

***Nomadic by Nature –
Adaptation Strategies to Ecological and
Socio-Economic Change Among Mongolian Herders
in the Dzungarian Gobi***

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submitted by

Lena Maria Michler

from Rheinfelden (Baden), Germany

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Examination Committee

Supervisor and Reviewer	PD Dr. Anna C. Treydte Department of Physical Geography Stockholm University, Sweden
Reviewer and Examiner	Prof. Dr. Ingo Grass Department of Ecology of Tropical Agricultural Systems University of Hohenheim
Examiner	Jun.-Prof. Dr. Andreas Schweiger Department of Plant Ecology University of Hohenheim
Head of the committee	Prof. Dr. Thilo Streck Department of Biogeophysics University of Hohenheim
Dean of the Faculty	Prof. Dr. Ralf Vögele

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Summary

Worldwide, pastoralism is the most common land use form practiced on extensive rangelands unsuitable for high-yielding agricultural production. For nomadic pastoralists, mobility is a key strategy since centuries to minimize grazing pressure on rangelands while providing nutritious forage resources to their livestock on pastures with high spatial-temporal resource variability. Herder mobility drastically declined in recent years due to changing socio-economic conditions, growing livestock numbers and climate change threatening both ecological and socio-economic resilience of pastures and herding communities.

In Mongolia, nomadic pastoralism is still practiced by one-third of the population. The country is sparsely populated and around 80% of the land is used for extensive livestock husbandry. While nomadic pastoralism was practiced on a subsistence level for centuries Mongolian herders are nowadays living to the rules of a market economy with cashmere as most important cash crop. As a former satellite state of the Soviet Union, Mongolia initiated a transition to a market economy leading to a privatization of the market following the collapse of the USSR in 1991. Coupled with the international growing demand for cashmere, livestock numbers peaked at 70 million livestock heads in 2019. In combination with climate change, this may have lead to as much as 77% of Mongolia's land now being considered degraded to a certain extent.

My study focused on the Dzungarian Gobi and the rangelands within and around the Great Gobi B Strictly Protected Area (SPA) in south-western Mongolia. This key biodiversity area is home to several threatened and endangered wildlife and plant species such as the Przewalski's horse (*Equus ferus przewalskii*), the Asiatic wild ass (*Equus hemionus*), and the Gobi desert plant Saxaul (*Haloxylon ammodendron*). The habitat is shared by nomadic herders and their livestock (goats, sheep, cows, horses and camels) who seasonally use the pastures within the limited use zone and buffer zone of the Great Gobi B SPA.

Rangelands are considered being important social-ecological systems (SES). Therefore, I applied an integrative data analysis framework in my study, combining quantitative environmental data with both quantitative and qualitative socio-economic information.

Achieving a deeper understanding of the mobility patterns of nomadic herders and the effects of grazing on Gobi pastures, I collected Global Positioning System (GPS) tracking data of 19 small livestock herds over 20 months. Mobility and flexibility emerged as important adaptive strategies for herder households in the Dzungarian Gobi. Herders in the Dzungarian Gobi adjust their mobility patterns, camp selection, and livestock grazing strategies in response to the spatio-temporal availability of plant biomass, reflecting their adaptation to fluctuating resource

availability. Herders changed their camp locations on average 9 times per year, covering a maximum distance between winter camps in the Gobi plains and summer camps in the Altai mountains of 70-123 km. Small livestock spent more than half of the day within a radius of 100 m from camp and livestock use intensity decreased steeply with distance from camp. Available plant biomass and season best explained camp use duration. Daily walking distance and maximum distance from camp increased with camp use duration. Pasture time increased with increasing plant biomass and rising temperatures.

I combined the GPS data with remotely-sensed environmental and climate data, and ground-based vegetation characteristics. Further, I determined herder preferences for camp selection in different plant communities based on focus group discussion data, and assessed the use and nutrient contents of the most important plant communities. In addition, I analysed plant species richness, vegetation cover, and plant biomass within different grazing radii around herder camps. Herders mainly selected their camp locations in *Stipa* spp. plant communities with highest nutritional value. I found little evidence for a corresponding grazing gradient in plant species richness, plant biomass, and cover on the Gobi plains.

Understanding the importance of altitudinal migration, I compared climatic conditions along the elevation gradient and determined seasonal body weight changes of goats and sheep. Lower summer temperatures and higher precipitation in the Altai mountains, resulted in higher productivity on summer pastures. Body weight of sheep and goats was slightly higher than the Mongolian average and body mass loss in winter was lower than in other parts of Mongolia.

Further, I conducted semi-structured interviews with 125 herder households, three focus group discussions, and two expert interviews with PA rangers, to better understand the socio-economic challenges of herder households, and the interaction of protected area (PA) management and herder households in the Great Gobi B SPA. I combined interview data with secondary data on regional and national herder households to determine the importance of social networks, willingness to continue a herding lifestyle, and degree of involvement in PA management. My descriptive data confirmed that herding is no longer centred on a subsistence lifestyle but rather around cashmere production. Contrary to sustainability goals, especially in protected areas, herder households continue to increase livestock numbers in response to high expenditures in the economic reality of a market economy. I conclude that herders in the Great Gobi B SPA are reaching neither socio-economically nor ecologically sustainable livestock numbers which challenge herders' livelihoods and PA management alike.

Fostering cooperation and communication between herder households in the PA management,

I tested paper diaries and small digital cameras as a tool to involve livestock herders as community-based rangers in the Great Gobi B SPA. I report the results of one herder who collected wildlife data over seven months as an example to show that his frequent wildlife sightings provide complementary information to data collected by rangers or scientists.

Rising livestock numbers, changing socio-economics, and climate change threaten pasture resources and the resilience of ecosystems and livelihoods dependent on these resources. This thesis provides an overview of Mongolian herders' adaption strategies to ecological and socio-economic change in the Dzungarian Gobi. Although there is only limited evidence of pasture degradation yet, high mobility and flexible pasture use combined with altitudinal migration is still a crucial practice in this system and should be fostered by policy-makers. Considering the effects of climate change and the socio-economic demands on herder households to raise livestock numbers, efficient pasture management is essential. Long-term environmental evaluations are required both inside and outside the Great Gobi B SPA, to identify changes in pasture ecosystems. Frequent livestock population monitoring and control measures are necessary to avoid overusing pasture resources and competition with wildlife, endangering the conservation of biodiversity and the livelihoods of herders. Through participatory activities, the Great Gobi B SPA management can involve local herder communities in conservation to enhance their understanding and improve communication. While herders in the Dzungarian Gobi have adapted to current ecological and socio-economic changes, it is a national responsibility to supporting herding communities by ensuring mobility, access to markets and social services, and create opportunities for economic diversification.

Zusammenfassung

Weltweit ist die Weidewirtschaft die häufigste Form der Landnutzung, besonders auf Flächen, die für die intensive landwirtschaftliche Nutzung nicht geeignet sind. Für nomadische Hirten ist Mobilität seit Jahrhunderten eine Schlüsselstrategie, um den Weidedruck auf Weideflächen zu minimieren und gleichzeitig ihrem Vieh nahrhafte Futterressourcen zur Verfügung zu stellen. Die Mobilität der Hirten hat in den letzten Jahren aufgrund veränderter sozio-ökonomischer Bedingungen, wachsender Viehbestände und des Klimawandels drastisch abgenommen, was sowohl die ökologische als auch die sozioökonomische Resilienz von Weiden und Hirtengemeinschaften bedroht.

In der Mongolei wird die nomadische Weidewirtschaft noch von einem Drittel der Bevölkerung ausgeübt. Das Land ist dünn besiedelt und rund 80 % der Fläche werden für die extensive Viehhaltung genutzt. Während die nomadische Weidewirtschaft jahrhundertlang auf Subsistenzniveau betrieben wurde, leben die mongolischen Hirten heute nach den Regeln der Marktwirtschaft, wobei Kaschmir die wichtigste Einnahmequelle ist. Als ehemaliger Satellitenstaat der Sowjetunion leitete die Mongolei mit dem Zusammenbruch der UdSSR im Jahr 1991 den Übergang zur Marktwirtschaft ein. Dies führte zu einer Privatisierung des Marktes. In Verbindung mit der international steigenden Nachfrage nach Kaschmir erreichte der Viehbestand im Jahr 2019 einen Höchststand von 70 Millionen Tieren. In Verbindung mit dem Klimawandel sind heute 77 % der mongolischen Böden bis zu einem gewissen Grad degradiert.

Meine Studie konzentrierte sich auf die Dzungarische Gobiwüste und die Weideflächen innerhalb und um das streng geschützte Gebiet Great Gobi B Strictly Protected Area (SPA) im Südwesten der Mongolei. Dieses Gebiet, reich an biologischer Vielfalt, beherbergt mehrere bedrohte und gefährdete Wildtier- und Pflanzenarten wie das Przewalski-Pferd (*Equus ferus przewalskii*), den Asiatischen Wildesel (*Equus hemionus*) und die Wüstenpflanze Saxaul (*Haloxylon ammodendron*). Der Lebensraum wird von nomadischen Viehzüchtern und ihrem Vieh (Ziegen, Schafe, Kühe, Pferde und Kamele) genutzt, die saisonal die Weideflächen innerhalb der begrenzten Nutzungszone und der Pufferzone der Great Gobi B SPA nutzen.

Weideland wird als wichtiges sozial-ökologisches System (SES) betrachtet. Daher habe ich in meiner Studie einen integrativen Datenanalyserahmen angewandt, der quantitative Umweltdaten mit quantitativen und qualitativen sozioökonomischen Informationen kombiniert.

Um die Mobilitätsmuster nomadischer Hirten und die Auswirkungen der Beweidung auf die Gobi-Weiden besser zu verstehen, sammelte ich ökologische Daten mit Hilfe von Global

Positioning System (GPS). Dabei habe ich 19 Kleinviehherden über 20 Monate hinweg verfolgt. Mobilität und Flexibilität erwiesen sich als wichtige Anpassungsstrategien für Hirtenhaushalte in der Dsungarischen Gobi. Die Hirten in der Dsungarischen Gobi passen ihre Mobilitätsmuster, die Wahl ihres Lagers und ihre Weidestrategien an die räumlich-zeitliche Verfügbarkeit von Pflanzenbiomasse an, was ihre Anpassung an die schwankende Verfügbarkeit von Ressourcen widerspiegelt. Die Hirten wechselten ihre Lagerplätze im Durchschnitt 9 Mal pro Jahr und legten dabei eine maximale Entfernung zwischen den Winterlagern in den Gobi-Ebenen und den Sommerlagern im Altai-Gebirge von 70-123 km zurück. Das Kleinvieh verbrachte mehr als die Hälfte des Tages in einem Umkreis von 100 m vom Lager entfernt, und die Intensität der Viehnutzung nahm mit der Entfernung vom Lager steil ab. Die verfügbare Pflanzenbiomasse und die Jahreszeit erklärten die Dauer der Lagernutzung am besten. Die tägliche Wanderdistanz und die maximale Entfernung vom Lager nahmen mit der Dauer der Lagernutzung zu. Die Weidezeit nahm mit zunehmender Pflanzenbiomasse und steigenden Temperaturen zu. Ich kombinierte die GPS-Daten mit aus der Ferne erfassten Umwelt- und Klimadaten sowie mit bodengebundenen Vegetationsuntersuchungen. Darüber hinaus ermittelte ich die Präferenzen der Hirten bei der Auswahl ihrer Lager in verschiedenen Pflanzengemeinschaften anhand von Daten aus Fokusgruppendifkussionen und bewertete die Nutzung und den Nährstoffgehalt der wichtigsten Pflanzengemeinschaften. Außerdem analysierte ich den Pflanzenartenreichtum, die Vegetationsbedeckung und die Pflanzenbiomasse in verschiedenen Weideradien um die Hirtenlager. Die Hirten wählten ihre Lagerstandorte hauptsächlich in Pflanzengemeinschaften von *Stipa* spp. mit dem höchsten Nährstoffwert. Ich fand wenig Anhaltspunkte für einen entsprechenden Gradienten durch Beweidung in Bezug auf den Artenreichtum, die Pflanzenbiomasse und die Vegetationsbedeckung in den Gobi-Ebenen.

Um die Bedeutung der Höhenwanderung zu verstehen, verglich ich die klimatischen Bedingungen entlang des Höhengradienten und bestimmte die jahreszeitlichen Veränderungen des Körpergewichts von Ziegen und Schafen. Niedrigere Sommertemperaturen und höhere Niederschläge im Altai-Gebirge führten zu einer höheren Produktivität auf den Sommerweiden. Das Körpergewicht von Schafen und Ziegen war etwas höher als im mongolischen Durchschnitt, und der Verlust an Körpermasse im Winter war geringer als in anderen Teilen der Mongolei.

Um die sozioökonomischen Herausforderungen der Hirtenhaushalte und das Zusammenspiel von Schutzgebietsmanagement und Hirtenhaushalten in der Great Gobi B SPA besser zu verstehen, führte ich semi-strukturierte Interviews mit 125 Hirtenhaushalten, drei Fokusgruppendifkussionen und zwei Experteninterviews mit Schutzgebietswildhütern durch. Ich kombinierte die Interviewdaten mit Sekundärdaten über regionale und nationale Hirtenhaushalte, um die

Bedeutung sozialer Netzwerke, die Bereitschaft zur Fortsetzung des Hirtenlebens und den Grad der Beteiligung am Schutzgebietsmanagement zu ermitteln. Meine beschreibenden Daten bestätigten, dass sich die Viehwirtschaft nicht mehr auf die Subsistenzwirtschaft, sondern auf die Kaschmirproduktion konzentriert. Im Gegensatz zu den Zielen der Nachhaltigkeit, insbesondere in den Schutzgebieten, erhöhen die Hirtenhaushalte weiterhin den Viehbestand als Reaktion auf die hohen Ausgaben in der wirtschaftlichen Realität einer Marktwirtschaft. Ich komme zu dem Schluss, dass die Hirten im Great Gobi B SPA weder sozioökonomisch noch ökologisch nachhaltige Viehbestände erreichen, was sowohl die Lebensgrundlage der Hirten als auch das Management der Schutzgebiete vor große Herausforderungen stellt.

Um die Zusammenarbeit und Kommunikation zwischen den Hirtenhaushalten innerhalb des Schutzgebiets zu fördern, testete ich Papiertagebücher und kleine Digitalkameras als Mittel zur Einbeziehung von Viehhirten als gemeindebasierte Wildhüter im Great Gobi B SPA. Ich berichte über die Ergebnisse eines Viehhirten, der sieben Monate lang Wildtierdaten gesammelt hat, um zu zeigen, dass seine häufigen Wildtiersichtungen ergänzende Informationen zu den von Wildhütern oder Wissenschaftlern gesammelten Daten liefern.

Steigende Viehbestände, sozioökonomische Veränderungen und der Klimawandel bedrohen die Weideressourcen und die Widerstandsfähigkeit der Ökosysteme und der von diesen Ressourcen abhängigen Lebensgrundlagen. Diese Arbeit gibt einen Überblick über die Anpassungsstrategien der mongolischen Hirten an den ökologischen und sozioökonomischen Wandel in der Dsungarischen Gobi. Obwohl es bisher nur wenige Anzeichen für eine Verschlechterung der Weideflächen gibt, ist die hohe Mobilität und flexible Weidenutzung in Verbindung mit Höhenwanderungen nach wie vor eine wichtige Praxis in diesem System und sollte von politischen Entscheidungsträgern gefördert werden. In Anbetracht der Auswirkungen des Klimawandels und der sozioökonomischen Anforderungen an die Hirtenhaushalte, den Viehbestand zu erhöhen, ist ein effizientes Weidemanagement unerlässlich. Um Veränderungen in den Weideökosystemen feststellen zu können, sind langfristige Umweltbewertungen sowohl innerhalb als auch außerhalb der Great Gobi B SPA erforderlich. Eine regelmäßige Überwachung des Viehbestands und Kontrollmaßnahmen sind notwendig, um eine Übernutzung der Weideressourcen und eine Konkurrenz mit wild lebenden Tieren zu vermeiden, die die Erhaltung der biologischen Vielfalt und den Lebensunterhalt der Hirten gefährden. Durch partizipatorische Aktivitäten kann das Management des Great Gobi B SPA die lokalen Hirtengemeinschaften in den Naturschutz einbeziehen, um deren Verständnis und Kommunikation zu verbessern. Die Hirten in der Dsungarischen Gobi haben sich zwar an die aktuellen ökologischen und sozioökonomischen Veränderungen angepasst, doch liegt es in der Verantwortung des Staates, die

Hirtengemeinschaften zu unterstützen, indem Mobilität gefördert, der Zugang zu Märkten und sozialen Dienstleistungen sichergestellt und Möglichkeiten zur wirtschaftlichen Diversifizierung geschaffen wird.

List of publications included in this thesis

In order to fulfil the criteria for a cumulative PhD thesis at the Faculty of Agricultural Sciences, several publications have been included in this this thesis.

Chapter 2:

Michler, L.M., Kaczensky, P., Ploechl, J.F., Batsukh, D., Baumgartner, S.A., Battogtokh, B., Treydte, A.C. (2022). Moving Toward the Greener Side: Environmental Aspects Guiding Pastoral Mobility and Impacting Vegetation in the Dzungarian Gobi, Mongolia. *Rangeland Ecology and Management*, 83, 149-160. doi.org/10.1016/j.rama.2022.03.006

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Chapter 3:

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The original publication is available at: <https://link.springer.com/article/10.1007/s10113-023-02126-y#citeas>

Chapter 4:

Michler, L. M., Kaczensky, P., Batsukh, D., & Treydte, A. C. (2024). What Will the Future Bring?—Socio-Economic Challenges to Herder Households in the Great Gobi B Strictly Protected Area in Mongolia. *Human Ecology*, 52(5), 1071-1085.

The original publication is available at: <https://doi.org/10.1007/s10745-024-00551-z>

Chapter 5:

Michler, L.M., Treydte, A.C., Dorjbat, B., Kaczensky, P. (2025). Through the eyes of a herder – Pilot project on using herders as citizen scientists in Great Gobi B strictly protected area in Mongolia. *Erforsch. biol. Ress. Mongolei (Halle/Saale)*

The original publication is accepted by: *Erforsch. biol. Ress. Mongolei (Halle/Saale)*

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List of abbreviations and acronyms

ADF	Acid Detergent Fibre
ADL	Acid Detergent Lignin
AIC	Akaike Information Criterion
CampStart	Start of Camp Use
CampUse	Camp Use Duration
CP	Crude Protein
DM	Dry Matter
EVI	Enhanced Vegetation Index
GGB	Great Gobi B Strictly Protected Area
GPS	Global Positioning System
HerderID	Herder ID
HerdRatio	Herd Ratio
HerdSize	Herd Size
MaxDist	Daily Maximum Walking Distance
NUM	National University of Mongolia
PA	Protected Area
PastureTime	Daily Pasture Time
PPRV	Peste des Petits Ruminants Virus
SD	Standard Deviation
SE	Standard Error
SeasonalCamp	Camps categorized by season and year of use
SES	Social-Ecological System
SFU	Sheep Forage Unit
SPA	Strictly Protected Area
TCAD	Total Cumulative Annual Distance
TEK	Traditional Ecological Knowledge
Temp	Temperature
UdSSR	Union der Sozialistischen Sowjetrepubliken
UN	United Nation
UNESCO	United Nations Educational, Scientific and Cultural Organization
USSR	Union of Soviet Socialist Republics
WalkDist	Daily Walking Distance
WWF	World Wildlife Fund

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Chapter 1 Introduction

1.1 Socio-Ecological Change in the Gobi

The expansive steppes of Central Asia and Mongolia form the largest connected dryland on Earth and support the livelihoods of around one-third of the region's population through extensive livestock husbandry (Ulambayar, 2021). In Mongolia, extensive livestock grazing is the most prominent land-use form (Angerer et al., 2008), practiced by one-third of the population (Mongolian Statistical Information Service, 2023). Today, herders live by the rules of a market economy and are no longer herding their livestock solely for subsistence (Lkhagvadorj et al., 2013b). Consequently, livestock numbers in Mongolia have reached record numbers, with over 70 million livestock heads reported in 2019 (Mongolian Statistical Information Service, 2023). Among these, cashmere goats (*Capra hircus*) have emerged as the primary source of income for nomadic herders (Berger et al., 2013). High-intensity grazing, combined with climate change, is seen as the main driver of rangeland degradation (Sainnemekh et al., 2022). Potential ecological and cultural tipping points (Fernández-Giménez et al., 2017) threaten both rangeland health, biodiversity, and the livelihoods of those people dependent on these natural resources. However, despite the importance of rangelands to both local livelihoods and natural ecosystems, few studies have interlinked ecological and social dimensions of pastoralism.

Understanding pastoralist systems requires three key pillars: (1) the influence of herders on the environment, (2) the livelihoods of livestock owners and herders, and (3) the link and potential challenges between these actors, the environment, and relevant institutions responsible for managing rangelands (Dougill et al., 2010). In this thesis, I focus on all three pillars within an arid ecosystem of the Mongolian Gobi desert.

1.2 Thesis Background

1.2.1 Rangelands globally

Rangelands cover 54% of the earth's terrestrial surface, spanning a wide range of biomes and ecozones (Figure 1.1; ILRI et al., 2021), and providing different ecosystem services. Ecologically, rangelands are key for providing habitat for flora and fauna, protecting fragile soils from erosion, increasing soil fertility, sequestering carbon and holding water resources (Briske, 2017). Socially and economically, rangelands are equally important, contributing to food security and poverty alleviation. Rangelands secure millions of livelihoods worldwide, and support

a large cultural diversity (Godde et al., 2020; ILRI et al., 2021; Lund, 2007).

Rangelands are commonly defined by their land cover and use type. Most rangelands are dominated by grasses and shrubs with extensive livestock production (Lund, 2007) practiced on 84% of rangelands worldwide (ILRI et al., 2021). The majority of rangelands (78%) are classified as drylands (ILRI et al., 2021; Millennium Ecosystem Assessment, 2005) and are often unsuitable for intensive agriculture production due to limited and highly variable interannual resource availability (Godde et al., 2020). Their location in extreme and fluctuating climate conditions (R. S. Reid et al., 2014) limit ecological and socio-economic productivity. Recently, pasture overuse and climate change threaten ecosystem functionality (Godde et al., 2020).

Rangelands face multiple challenges caused by land-use change and overuse (Lund, 2007) which are coupled with economic and political stressors, and are multiplied by climate change (Reid et al., 2014; Reid-Shaw et al., 2021). Land use changes are fostered by global population growth, resulting in high demands for food and energy consumption (Herrick et al., 2012). Still, most of the rangelands are used extensively and are characterized by a comparably sparse human population with often limited market access (Reid et al., 2014).

While rangelands have been recognized as important social ecological systems (SES; Chen et al., 2018), range science and management often fails to connect both disciplines, resulting in either ecological or social solutions without recognizing their interactions and interdependencies (Hruska et al., 2017). Often, SESs in rangelands focus on potentially competing goals (Hruska et al., 2017) such as wildlife conservation and livestock grazing, where management solutions are needed to satisfy different interests.

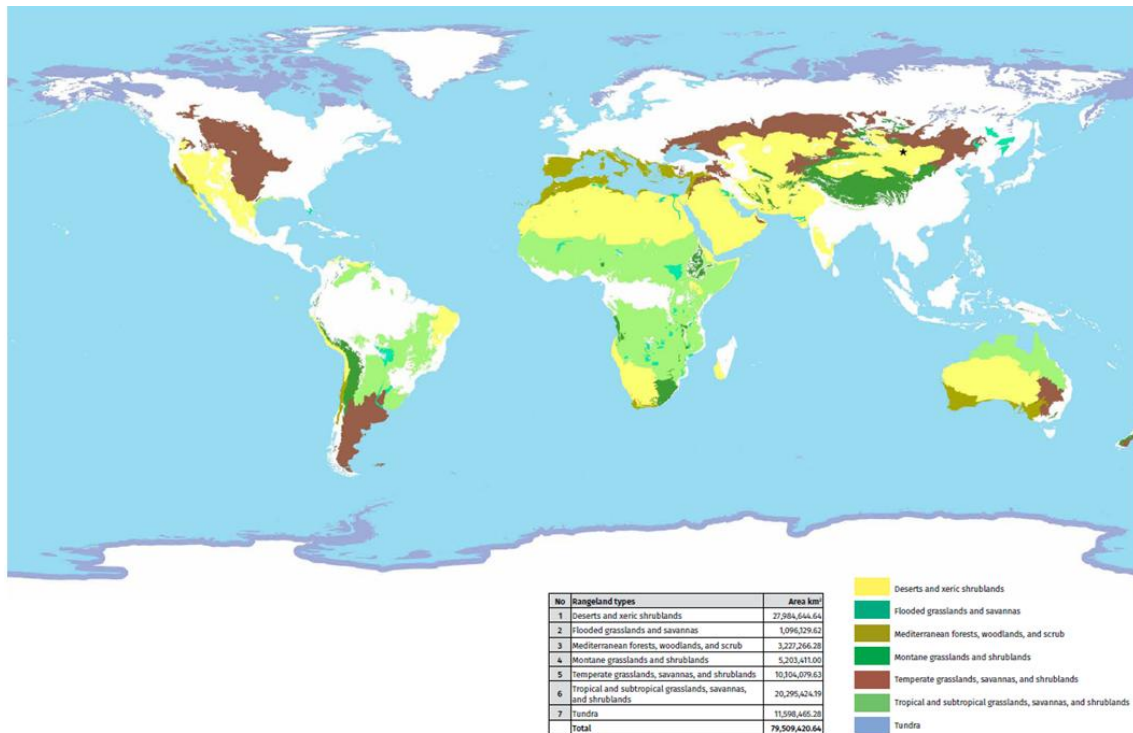


Figure 1.1: Global distribution of rangeland types. The * marks the location of the study area in Mongolia. Source: ILRI et al. (2021)

1.2.2 Pastoralism on rangelands

The global distribution of pastoralism is vast as it accounts for the most common land use form worldwide (Figure 1.2; Reid et al., 2014). Especially in desert areas livestock production is the most significant anthropogenic land-use form (Wuerthner, 2020) shown by the map of pastoralists worldwide covering over 950 groups of pastoralists (League for Pastoral Peoples, 2025; Figure 1.2).

Pastoralism describes the practice of domestic herbivore keeping (Little, 2015), dating back to the earliest domesticated animals (excluding dogs): goats (*Capra hircus*) and sheep (*Ovis aries*) 11,000 years ago, and cattle (*Bos taurus*) 10,000 years ago in the Near East (Zeder, 2008). Pastoralists worldwide commonly keep herbivores that need pasture and have a natural tendency to migrate to find sufficient forage resources (Behnke et al., 2011; Little, 2015).

Wild migrating ungulates select for high forage quality, while following vegetation green-up and surfing the so-called “green-wave” (Bischof et al., 2012; Fryxell & Avgar, 2012). According to the “forage-maturation hypothesis” (Hebblewhite et al., 2008), wild migrating ungulates wander from areas where they gain weight and reproduce to places where they survive during harsh weather or times of forage shortage (Abraham et al., 2022; Sawyer et al., 2019).

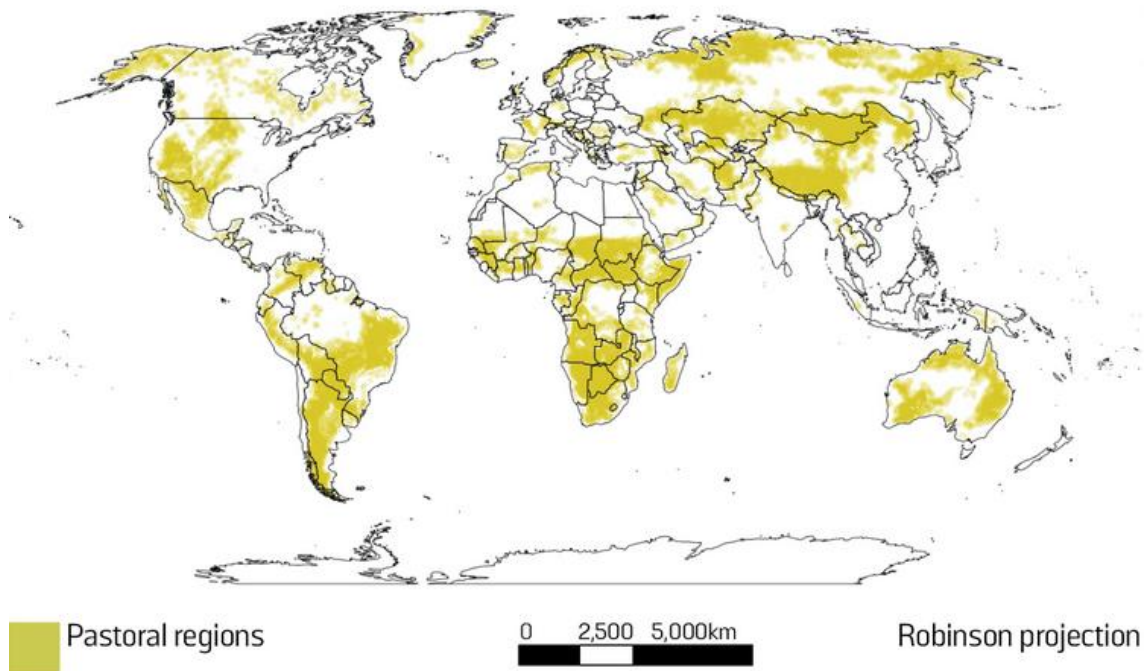


Figure 1.2: Global distribution of pastoralists. Source: adapted from Houzer & Scoones, 2021 and IUCN & UNEP, 2015

Wild and domestic ungulate migrations occur on every continent worldwide (Little, 2015; Manzano et al., 2021a), and are influenced by (1) quantity, quality and distribution of forage resources, (2) competition with other ungulates for food resources, and (3) different factors such as predation, parasites, climate or terrain hindering or facilitating access to this resource (Behnke et al., 2011).

Pastoral mobility mimics the behaviour of migration animals (Behnke et al., 2011), and this mobility can be divided into three types (Figure 1.3): (1) Nomadism, often practiced as horizontal migration, is common from the tropics to the Arctic, in deserts and savannas, taiga and tundra, steppes, plains and marshes, and is characterized by irregular and opportunistic movements of nomadic pastoralist searching for the most nutritious vegetation for their livestock (Behnke et al., 2011; Blench, 2001). (2) Transhumance, characterized by regular movements from a fixed homestead to seasonal available pastures, often occurs as altitudinal or vertical migration (Blench, 2001) practiced in temperate Asia. (3) In the alpine systems in Europe, livestock moves from the low-lands with a fixed stable to the higher altitudes spending the growing season on nutritious pastures (Behnke et al., 2011; Luick, 2008).

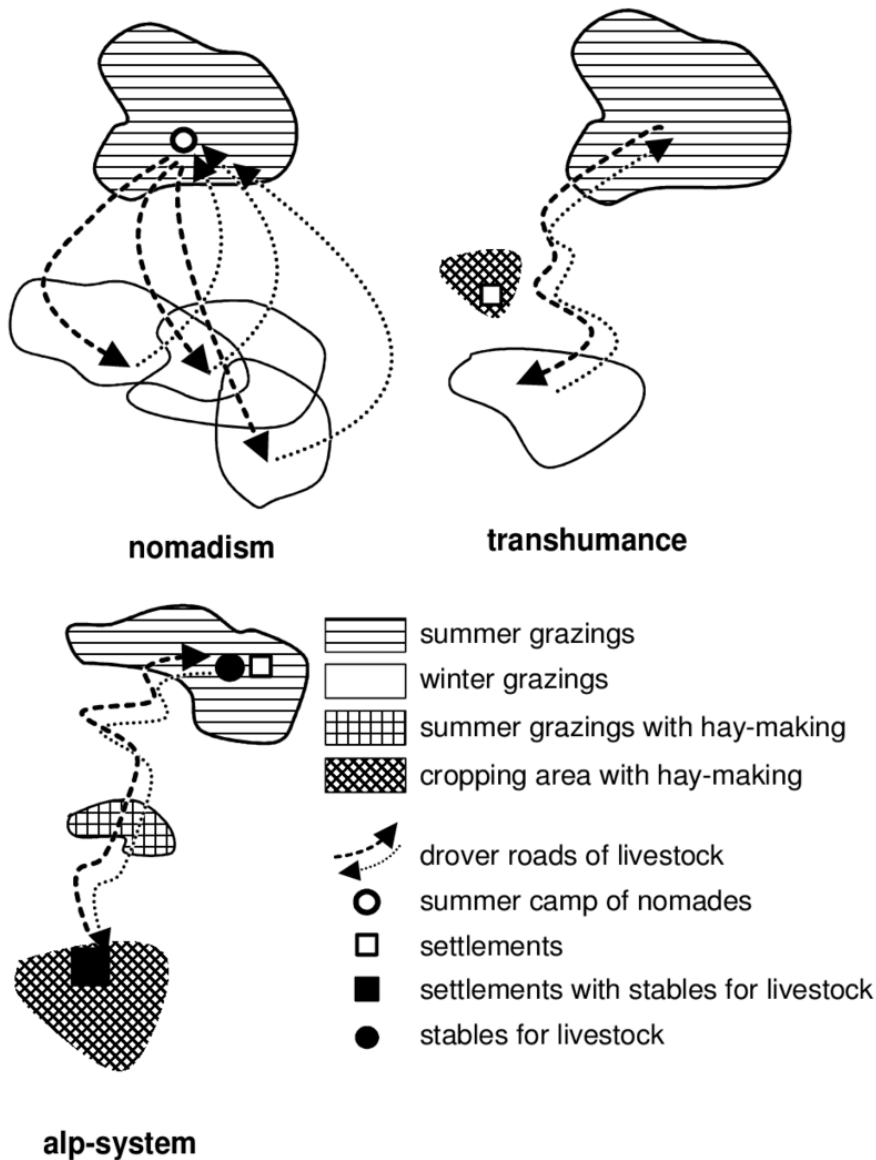


Figure 1.3: Different pastoral migration patterns. Source: Luick (2008)

Many pastoralists worldwide manage mixed herds, combining two or more livestock species - such as cattle, goats and sheep - particularly in landscapes with heterogeneous forage availability (Anderson et al., 2012). This practice not only benefits the landscape but also enables pastoralists to diversify their use of livestock products compared to mono-species herds (Anderson et al., 2012). The choice of livestock species and the herding management strategy are thereby adapted to the rangeland features and conditions (Herrera et al., 2014). The selection of local species and breeds with particular physiological characteristics, especially body size, allows herders to adapt the impact of grazing on pastures (Rook et al., 2004).

Pastoralism provides economic, social and cultural value to the livelihoods of 200 to 500 million people worldwide (Mbow et al., 2019). Pastoral practices are, thereby, influenced by

economic, social and environmental factors and are frequently prone to adaptation to change, making pastoralism a highly resilient lifestyle (Mekuyie et al., 2018; Pollini & Galaty, 2021). Ecologically, pastoralism contributes significantly to rangeland health, productivity and resilience (UNCCD, 2024).

Mobility is the most important adaptation strategy of pastoralists to provide livestock with sufficient forage resources and distribute grazing pressure on rangelands (Coughenour, 1991; Liao et al., 2017). Interview data and participatory mapping have been commonly used by multiple studies (Altmann et al., 2018; Ono & Ishika, 2020; Samuels et al., 2019) to better understand pastoral mobility patterns. Recently, Global Positioning Systems (GPS) have been applied in different pastoral systems to track individual and herd mobility and gain understanding of the animals spatial and temporal usage of the landscape (Adriansen & Nielsen, 2005; Butt, 2010; Liao, 2018; Swain et al., 2011). In the last decades, satellite imagery data has become more popular as a tool providing the possibility to observe environmental parameters on large spatial and temporal scales (Boyle et al., 2014). While satellite data alone cannot provide enough information about pastoral grazing systems (Shibia et al., 2022), integrating such tools in the data collection can detect land cover changes and the need for conservation measures (Boyle et al., 2014). In this thesis, I combined GPS and satellite imagery data over several years with interviews and environmental assessments to understand nomadic pastoral migration patterns in an arid region of Mongolia.

Within pastoral systems, nature and society are closely interlinked (Chen et al., 2018) but few studies have looked at both spatial scales of rangeland use and on associated social aspects of local herders. These social-ecological systems (SES) are hotspots of biological and cultural diversity (Kaufmann et al., 2016; Lankester & Davis, 2016; Zinsstag et al., 2016) but social and natural vulnerabilities threaten people's livelihoods and rangeland health due to global environmental change (López-i-Gelats et al., 2016). In the next chapters, I focus on environmental challenges to herders and describe social and political aspects influencing the nomadic pastoral livelihoods.

1.2.3 Environmental challenges to pastoral livelihoods

Livestock numbers are on the rise globally due to population growth, a growing demand for meat and milk (FAO, 2022), and higher demands for niche products such as cashmere wool (Rysbyek & Lei, 2022). Worldwide, grazed systems in arid regions are threatened by pasture degradation and desertification due to rising livestock numbers (The Grassland Alliance, 2024), and climate change effects. In these dry rangelands, highly variable spatial and temporal

precipitation is common (Espeland et al., 2020; Vandandorj et al., 2015). Climate change is expected to increase the frequencies of extreme weather events such as drought, floods, and extreme temperatures (Han et al., 2021; Herrero et al., 2016). According to the Intergovernmental Panel on Climate Change, the average global temperature has already increased by about 1.1°C since the last century (IPCC, 2023), and, pastoralists in particular are challenged by the effects of climatic change (Thornton et al., 2009). Changes in temperature and precipitation alter forage quantity and quality and change plant composition on pastures (Giridhar & Samireddypalle, 2015; Polley et al., 2013). Increased atmospheric CO₂ levels due to climate change benefit woody plants, and, thus, shrubs often encroach into grasslands (Archer et al., 2017). Globally spreading invasive species further reduce pasture availability and quantity (Morgan et al., 2007). Further temperature rise will change foraging behaviour (Horie et al., 2023), increase the risk of heat stress for livestock (Thornton et al., 2009), and ultimately lead to decreased livestock production efficiency (Goma & Phillips, 2022). Varying water availability due to climate change will impact pastoral mobility patterns (Tugjamba et al., 2021b). These environmental challenges threaten the ecological and socio-economic sustainability of pastoral livelihoods.

In this thesis, I analysed pastoral travel timing and routes as well as livestock grazing mobility to better understand pastoral adaptation to environmental factors. I combined Global Positioning System tracking data of goats, remotely sensed pasture productivity, and ground-based vegetation characteristics in the Mongolian Gobi. I further highlighted the importance of altitudinal migration in this rangeland system for seasonal body weight changes of small livestock.

1.2.4 Social and political challenges to pastoral livelihoods

Globally, the livelihoods of millions of pastoralist are challenged through unsustainable land-use practices, and socio-economic changes (Tugjamba et al., 2021b). The forces of colonialism gradually limited pasture access of herders in the past (Bhattacharya, 2019; Hoffman & Rohde, 2007). This led to the destruction of the entire transhumance pattern, such as that of Nama herders in South Africa (Cousins et al., 2007). The effects of this destruction are still visible today, limiting pastoral management practices in many parts of the world (Michler et al., 2019; Samuels et al., 2007).

Although mobility is key to pastoral adaptation strategies, many governments worldwide foster the sedentarisation of nomadic pastoralists until today, e.g., in the province Xinjiang, China (Liao & Fei, 2017), in the Tibet Autonomous Region of China (Nyima & Yeh, 2023), or in Cameroon (Reeves, 2016) and Ethiopia (Degen, 2011). Further, displacement of pastoralists

occurs due to political conflicts and wars (Richards, 2024). Even the establishment of protected areas has led to the expulsion of pastoralists (Singh et al., 2022). Before the 1980s, many people worldwide were evicted in the name of conservation, leaving them without homes or economic opportunities to maintain their livelihoods (Brockington & Igoe, 2006). This so-called “green grabbing” has been common in drylands (Gargallo et al., 2022). The Ngorongoro Conservation Area in northern Tanzania, where Maasai pastoralists share natural resources with wildlife has been a prime example of human-wildlife co-existence since 1959 (UNESCO World Heritage Convention, 2024). However recently, the local pastoral community has been displaced causing a global outrage (Oleshangay, 2022).

Most pastoralists worldwide have access rights to pastures or land tenure rights without owning the land (Herrera et al., 2014). Land tenure rights are based on international, regional and local laws and policies, tradition, culture and/or religion (Herrera et al., 2014). Land tenure can be categorized as open access without any specific rights for anyone, communal with rights for the commons, state property rights, or private (FAO, 2002). On some rangelands, different tenure rights apply causing a complex governance structure. Sometimes natural resources on the same land such as water, wood or pasture are under different tenure rights (Herrera et al., 2014). The disruption of governance rights poses a major threat to many pastoral communities (Davies et al., 2016).

Further conflicts are often seen between human and wildlife (Alexander et al., 2015; Su et al., 2023) or between pastoralists and farmers (Mbah et al., 2021) using the same natural resources. Land-use changes through, e.g., mining activities (Sternberg et al., 2022), industries, high-intense agricultural production or infrastructure development such as roads and railways limit pasture access of herders resulting in less resource availability and decline of pastoral mobility (Manzano et al., 2020). Further, lacking access to social services like education and health is a major challenge to herders around the world (Caine, 2021; Dika et al., 2021; Dyer & Rajan, 2023; Gammino et al., 2020). These challenges triggered by the trend from nomadic to sessile forms of livestock grazing and rural-urban migration have increased worldwide (Dyer et al., 2022; Wafula et al., 2022).

All these difficulties and the harsh work and life conditions make herding an unattractive livelihood for the global youth (Schlecht et al., 2020). Therefore, alternative pastoral management strategies are evolving, and absentee and contract herding arrangements become more popular (Mijiddorj et al., 2019; Murphy, 2015). These arrangements can negatively affect pasture health and livestock well-being (Michler et al., 2019; Moritz et al., 2011). The limited access to

markets often impedes the possibility of herders to sell their livestock products, challenging their already small economic profit margin (Meurs et al., 2017).

Therefore, diversification of household incomes is often promoted by policy-makers to increase herder livelihood resilience (Dinku, 2018; Liao et al., 2015; Watete et al., 2016). However, several studies concluded that livestock herding remains the most important income generation activity for pastoral livelihoods (Achiba, 2018; Dinku, 2018). Thus, policies supporting sustainable pastoral activities, providing flexible pasture use (Liao et al., 2015; Watete et al., 2016), and facilitating market access (Meurs et al., 2017) should be promoted and supported by policy institutions.

In this thesis, I combined interview data of herder households in an arid and remote region of Mongolia with secondary data on regional and national herder households to determine livelihood trends such as livestock herd sizes, household economy, daily and seasonal labour divisions, and the future of traditional herding in pastoralist communities.

1.2.5 Pastoralism within protected areas

Two theories are often debated in the scientific community: (1) land sharing, where agricultural production in a wildlife-friendly way enables biodiversity conservation and food production on the same land, and (2) land sparing, where land is strictly divided into protected areas and high-yielding agricultural production (Grass et al., 2019; Phalan et al., 2011).

Globally, 12% of rangelands as important SESs are classified as protected areas (ILRI et al., 2021). Prior to the 1990s, prioritizing wildlife management within protected areas over the needs of the local population was common (Makombe, 1993). As a result, many local communities were compelled to abandon the land they had inhabited for generations (Reid et al., 2004).

Starting in the 1990s, conservation managers have become more aware of integrating local actors to achieve sustainable resource use (Carruthers, 1993; Hutton & Leader-Williams, 2003), and Man and Biosphere Reserves were created by the United Nations Educational, Scientific and Cultural Organization (UNESCO) in 122 nations (UNESCO, 2025). In 2022, the global community agreed at the 15th Conference of Parties to the UN Convention on Biological Diversity to set aside 30% of the world's lands, inland waters, coastal areas and oceans by 2030. Under target 3 of the "30 by 30" initiative, protected and conserved areas are to be enhanced and expanded. At the same time, the rights of indigenous peoples and local communities have to be respected and recognized (Convention on Biological Diversity, 2022).

The sustainable shared use of natural resources is one aspect inside protected areas and in the

buffer and transition zones surrounding protected areas (Stoll-Kleemann & Welp, 2008), which is especially important in areas where pastoralism is practiced. Management and policy decisions, however, can have far-reaching consequences on ecosystems and livelihoods of people (Briske et al., 2020). For example, governmental supplementary feeding programs on arid rangelands lead to degradation and high costs on the long-term (Schulze et al., 2016).

In and around protected areas, land-use conflicts are increasing (DeFries et al., 2007) through the global rise of livestock numbers (FAO, 2022) in grazed systems. Livestock grazing practiced within protected areas challenges biodiversity conservation, wildlife management (Kaczynsky et al., 2020; Salvatori et al., 2021), and rangeland health (Ghoddousi et al., 2024). However, local communities can be powerful allies for the protection of pasturelands as local communities and conservation practitioners both aim for healthy pastures (Bedunah & Angerer, 2012; Hess et al., 2010).

The study site for this thesis was the Great Gobi B Strictly Protected Area (SPA) in Mongolia. There, local pastoralists and their livestock share pasture and water resources with wildlife in the limited use zone of a strictly protected area and the surrounding buffer zone. To understand pastoral involvement in the protected area (PA) management of the Great Gobi B SPA, I conducted semi-structured interviews and focus group discussions with herders and PA rangers. In addition, I tested wildlife diaries as a tool to involve herders as citizen scientists to collect wildlife observation data.

1.2.6 Rangelands and pastoralism in Mongolia

Mongolian rangelands belong to the eastern part of the Eurasian Steppe, the world's largest grassland region, ranging from Hungary in the West to China in the East covering 8,000 km of grassland (Figure 1.4; Encyclopædia Britannica, 2024). The ecological importance of the Eurasian Steppe biome is a consequence of its massive size (Wesche et al., 2016). The biome is hosting a large flora of herbaceous plants (Dengler et al., 2014), and stores ample amounts of carbon in the steppe soils (Zhao et al., 2017). The Eurasian Steppe rangelands enable extensive ungulate migrations (Harris et al., 2009), provide habitats for specialised small mammals (Formozov, 1966), and are used for extensive mobile pastoralism since centuries (Khazanov, 2003).

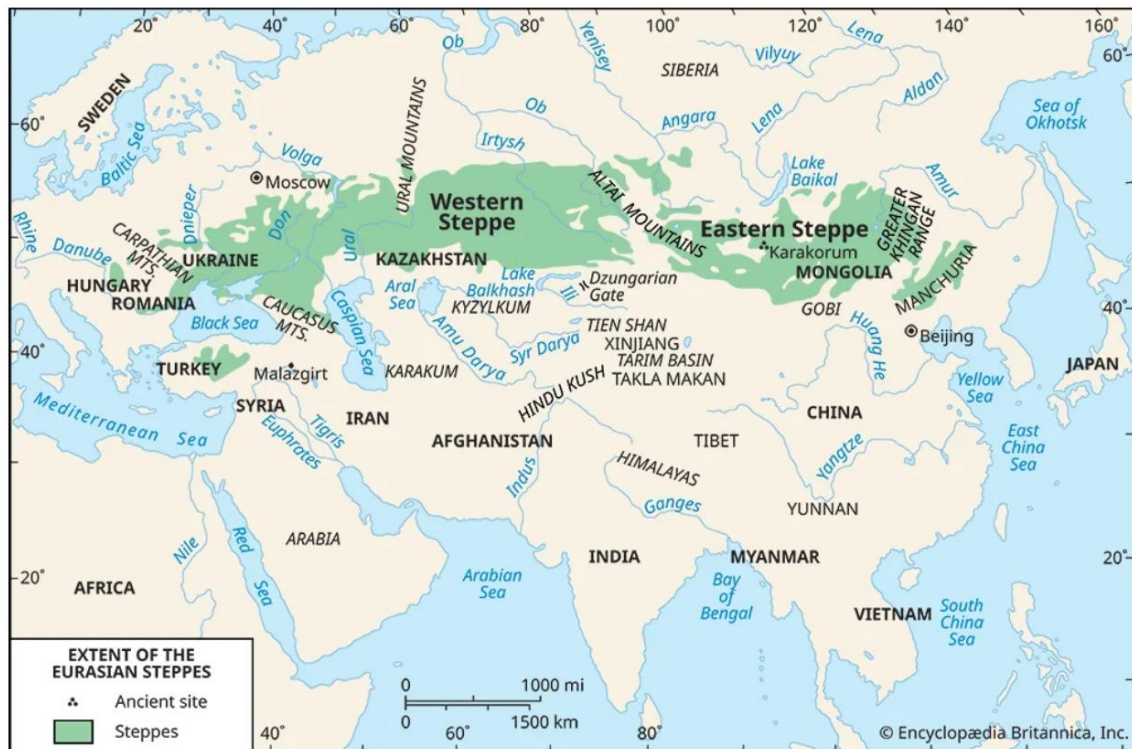


Figure 1.4: The Eurasian Steppe. Source: Encyclopædia Britannica (2024)

The Mongolian grasslands cover 1,2 million km² (Pfeiffer et al., 2020), accounting for over 80% of the land used for extensive livestock husbandry in the country (Angerer et al., 2008). The Mongolian rangelands spread from the forest steppe in the North, over the typical steppe in central Mongolia to the Gobi desert in the South (Pfeiffer, 2018).

In Mongolia, pastoral livelihoods have been practiced for millennia and pastoralism is still today securing the livelihoods of one-third of the Mongolian population (Mongolian Statistical Information Service, 2023). For thousands of years, Mongolian herders lived on subsistence livestock production, mainly using the meat, milk, wool and skin products of their livestock (Johnson et al., 2006).

During the Soviet era starting in the 1920s, Mongolia was a satellite state and herders belonged to collective cooperatives and did not own their own livestock (Johnson et al., 2006). The changes from summer to winter pastures, winter feeding and veterinary care were organized by the state (Fernández-Giménez, 1999; Johnson et al., 2006). With the fall of the Soviet Union in 1991, the collective era came to an end. Many people lost their jobs and started herding as an occupation again, while control mechanisms were no longer in place. This led to a sharp increase in livestock numbers and unsustainable pasture use (Figure 1.5; Fernández-Giménez, 1999). Combined with the rising international demand for cashmere wool the economy of herder households changed from subsistence to a market economy (Meurs et al., 2017).

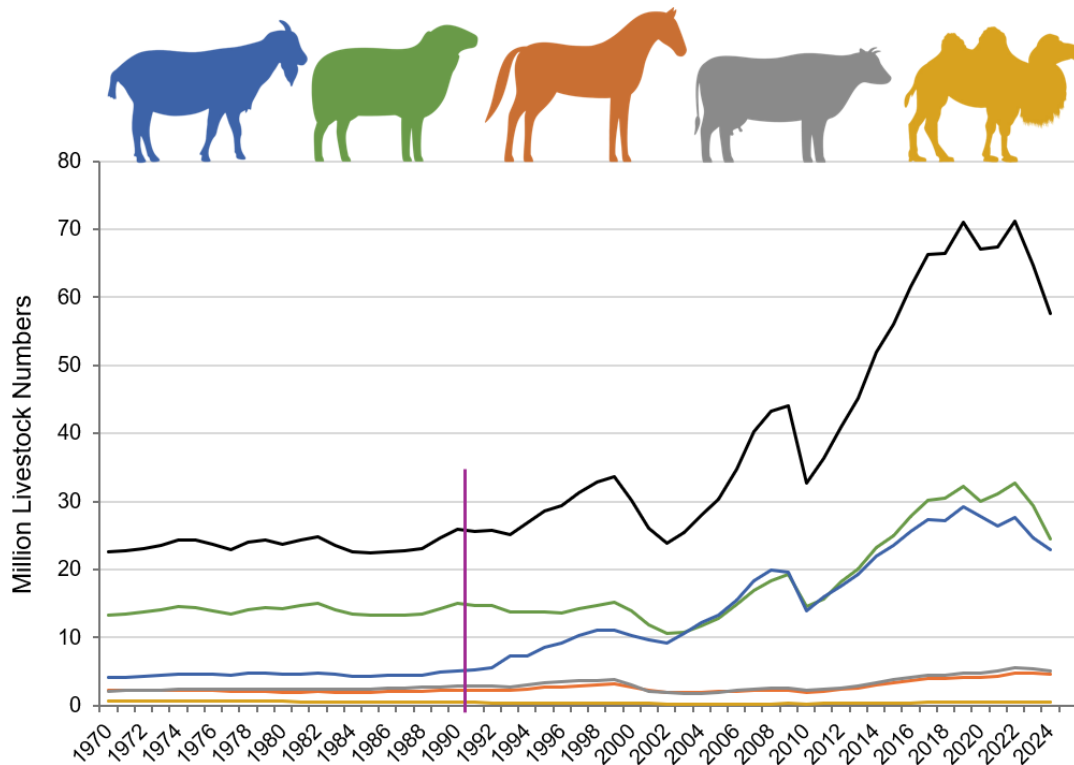


Figure 1.5: Livestock numbers in Mongolia from 1970 to 2024 based on national census data (Mongolian Statistical Information Service, 2025). Colours represent different livestock species and the black line shows the total livestock population trends. The purple line marks the year of the Soviet Union fall (1991), after which livestock numbers increased sharply.

Livestock numbers peaked at 70 million livestock heads in the year 2019 due to growing economic demands by herder households (Mongolian Statistical Information Service, 2023) and socio-economic changes (Xu et al., 2019). Overgrazing and overuse of natural resources led to soil degradation, plant species diversity loss, decrease of palatable plant species, ultimately resulting in land degradation (Sainnemekh et al., 2022). According to UNDP (2020), 77% of the land in Mongolia is nowadays degraded to a certain extent, although the assessment of what is degraded and how to assess it is still debated.

Mongolian rangelands are characterized as non-equilibrium system. Such systems experience highly variable precipitation patterns, seasonally, annually and spatially (Fernández-Giménez & Allen-Díaz, 1999). Vegetation quantity is thereby mainly influenced by the amount and distribution of precipitation. The fluctuating forage availability in combination with extreme winter events, so-called dzuds, have in recent years “down-regulated” the livestock numbers in Mongolia, albeit with catastrophic social-economic effects for local herder communities (Fernández-Giménez et al., 2015). Recently, winter feeding has become more common (Tugjamba et al., 2021a), bringing some relief to impacted herders and their livestock, but further

contributing to increasing livestock numbers.

The high livestock numbers come on top of the environmental challenges of climate change (Tugjamba et al., 2021b). In Mongolia, climate change impacts are severe and already resulted in an overall temperature increase of 2°C and permafrost has been thawing with a decline of 35% in the last 70 years (Ma et al., 2024) leading to forest dieback (Juříčka et al., 2020). The impact on precipitation is less clear although some sources note declining rainfall amounts between the years 1940 and 2015 (World Bank Group & Asian Development Bank, 2021), decreasing summer precipitation (Angerer et al., 2008), and drying out and increased salinization of rivers and lakes (Tandon et al., 2020; Tao et al., 2015). However, some of these observations are based on local, regional or short term observations.

Average annual temperatures in Mongolia are on the rise but climate change is expected to bring a higher probability of extreme weather events, including increased dzud risks in winters (Rao et al., 2015). These extreme winter events are characterized as a combination of very low temperatures, heavy snow fall, or icing events which are the main cause for climate related mass mortality of livestock populations in Mongolia (Begzsuren et al., 2004). During dzud events, livestock mortality has been dramatically high due to a combination of different factors: (1) inaccessible fodder caused by ice or snow, (2) weak health conditions due to poor grazing conditions in the previous summer, (3) exposure to extreme cold temperatures, winds and storms, (4) weak immune systems, and (5) miscarriages of female livestock during these harsh winters (Begzsuren et al., 2004; Fernández-Giménez et al., 2012; Rao et al., 2015). Such severe livestock losses affect the livelihoods of pastoralists, as the income earning potential is reduced, and some families loose all of their livestock, forcing them to give up the herder lifestyle (Ahearn, 2018).

Herder and livestock mobility has been primarily studied through interview data in Mongolia (Lkhagvadorj et al., 2013a; Ono & Ishikawa, 2020). Only few studies have looked across different spatial scales (Teickner et al., 2020) or interlinked social (Fernández-Giménez et al., 2018; Fernández-Giménez & Febre, 2006; Mocellin & Foggin, 2008) with ecological (Fernández-Giménez, 2000; Lang et al., 2020; Narantsetseg et al., 2018) disciplines.

To close this knowledge gap, I applied an integrative data analysis framework in this thesis. I combined GPS data of livestock herds, remote sensing data characterizing pasture at the landscape scale, vegetation assessments at the local scale, and complemented those data with traditional ecological knowledge, to better understand drivers behind herder travel mobility and analyse the impact of grazing mobility around herder camps. In addition, I identified the

importance of livestock and herder mobility, to explain what triggers camp moves of pastoralists in Mongolia, which factors influence grazing mobility around camps, and how altitudinal migration benefits small livestock.

1.2.7 The Mongolian Gobi desert environment

Asia's largest desert, the Gobi, stretches over 1,300,000 km² in southern Mongolia and north-western China (Figure 1.6; McCarthy et al., 2022). The Gobi basin is framed by the Altai and Khangai mountains in Mongolia and the Himalayan Plateau in China (Heiner et al., 2020). In this cold desert with continental climate, precipitation is scarce with 50-200 mm (Esposito et al., 2024; McCarthy et al., 2022). Precipitation varies interannually and spatially leading to a non-equilibrium system (Fernández-Giménez & Allen-Diaz, 1999). The winters are long and cold with temperatures down to -40°C, and summers are short and hot with up to +40°C (Sternberg et al., 2015). The characteristic arid vegetation of the Gobi desert is a mix of steppe vegetation, desert grasslands and true desert with many endemic species (Magsar et al., 2018).

The Gobi desert belongs to the least populated places on earth with little anthropogenic influence (Sternberg, 2015). However, nomadic pastoralism has been practiced there for thousands of years as a well-adapted lifestyle to this arid region (Vanwezer et al., 2021). Although the “water-less place” - as the Gobi desert is called in the Mongolian language - is a harsh environment, it comprises a vast plant and animal biodiversity, with 33 species being listed as threatened or endangered (McCarthy et al., 2022). The Gobi is home to the world's largest populations of migratory Asiatic wild ass (*Equus hemionus*, called khulan in Mongolian), goitered gazelle (black-tailed gazelle, *Gazella subgutturosa*), and Mongolian gazelles (*Procapra gutturosa*; Batsaikhan et al., 2014; Buuveibaatar et al., 2017). In addition, the Gobi is home to the highly endangered and endemic Gobi bear (*Ursus arctos gobiensis*; Tumendemberel et al., 2021) and one of the three remaining populations of wild Bactrian camel (*Camelus ferus*) lives in the Gobi desert (Xue et al., 2021). In the south-western part of the Gobi, the Przewalski's horse (*Equus ferus przewalskii*, called takhi in Mongolian) was reintroduced over 30 years ago after its extinction in the wild (Kaczensky et al., 2007). In the mountainous regions of the Gobi, Argali sheep (*Ovis ammon*), Siberian ibex (*Capra sibirica*) and Snow leopard (*Panthera uncia*) are found (Batsaikhan et al., 2014).

The Mongolian government has established several protected areas in the Gobi; the Great Gobi Strictly Protected Area (SPA) A and B is one of the largest terrestrial protected areas in the world, and was established in the year 1975 (McCarthy et al., 2022). In 1991, the Great Gobi SPA A and B was registered as UNESCO Man and Biosphere Reserve and in 2019, Great Gobi

B was doubled in size from 9,000 to 18,000 km², so that the Great Gobi SPA is now spanning over 62,000 km² (McCarthy et al., 2022).



Figure 1.6: The location of the Great Gobi B Strictly Protected Area in the Gobi desert as defined by WWF (Olson et al., 2001; Dash, 2007). Source: adapted from Heiner et al. (2020)

1.3 Aims and Objectives of this Thesis

This study was conducted in the Dzungarian Gobi in south-western Mongolia. Here, the Great Gobi B SPA stretches over 18,000 km² semi-desert and desert-steppe vegetation (Figure 1.6, Sansarbayar, 2019; von Wehrden et al., 2006). The biodiversity hotspot Great Gobi B SPA is home to several endangered wild ungulates, such as the Przewalski's horse and the Asiatic wild ass (Kaczensky et al., 2008). Around 280 herder households have seasonal access to the pasture resources within the limited use zone of the Great Gobi B SPA and livestock. However, rising livestock numbers (Mongolian Statistical Information Service, 2023) raise concern over pasture health, competition with wild herbivores, disease transmission, and hybridisation (Kaczensky et al., 2020; King et al., 2015).

The main objective of this thesis was to better understand the mobility patterns of nomadic herders, the grazing impacts on the Gobi pastures, the socio-economic challenges of herder households, and the interaction between the local herders and the Great Gobi B SPA management.

The specific objectives were to:

- (1) Identify key determining environmental factors of pastoral travel mobility and camp selection across seasons.
- (2) Determine camp selection according to different plant communities and their forage quality.
- (3) Investigate the grazing intensity around herder camps and quantify how intensity impacts the vegetation and soils around herder camps.
- (4) Assess environmental and social factors that influence herders' camp use duration and livestock herd movements.
- (5) Explore the socio-economic situation of pastoral livelihoods under ongoing social and economic changes.
- (6) Understand the perception of herders on using the pasture resources of the Great Gobi B SPA and their interaction with the protected area (PA) management.
- (7) Test in a pilot project if herders as citizen scientists can collect wildlife observation data for the PA management.

In this thesis, I combined ecological and socio-economic research at landscape, regional, and local scale. I used Global Positioning System (GPS) tracking data of small livestock herds (goats and sheep), to better understand drivers behind travel mobility of herders and their livestock and the influence of grazing on pastures. Then, I combined this data with remotely sensed pasture productivity, and applied ground-based vegetation and soil characteristics. Through semi-structured interviews and focus group discussions I obtained an insight into the socio-economic situation of herder households and their relationship with the PA. To get insight into herder-wildlife interactions I tested the suitability of herder diaries to record wildlife observations.

1.4 Outline of the Thesis

This dissertation is a cumulative thesis, with three peer-reviewed and published, and one submitted journal article representing each chapter (Figure 1.7).

In chapter 2, I described the travel mobility and livestock grazing patterns of herders, measured by Global Positioning Systems (GPS) tracking data and analysed remotely sensed pasture productivity on landscape scale. I determined ground-based vegetation characteristics such as

plant biomass, plant species richness and vegetation cover and looked at environmental factors that influence herders' spatio-temporal camp moves.

In chapter 3, I used GPS data of goat herds to analyse what triggered camp moves of herders in the Great Gobi B SPA, which factors influenced grazing mobility around camps, and how altitudinal migration benefited small livestock.

In chapter 4, I combined interview data of herder households in the Great Gobi B SPA with secondary data on national and regional herder households. I describe herd management and income from various livestock products, and determined the importance of social networks, willingness to continue a herding lifestyle, and the degree of involvement in PA management.

In chapter 5, I described a pilot study of a citizen science approach to engage herders in the collection of wildlife observation data.

In chapter 6, I discussed the main findings of this thesis and addressed interlinkages and limitations of this study. Further, I describe the importance of a holistic view on the integration of human land use in nature conservation and highlight additional challenges of herding in the Great Gobi B SPA. In addition, I propose recommendations for more sustainable pasture use in and around the Great Gobi B SPA.

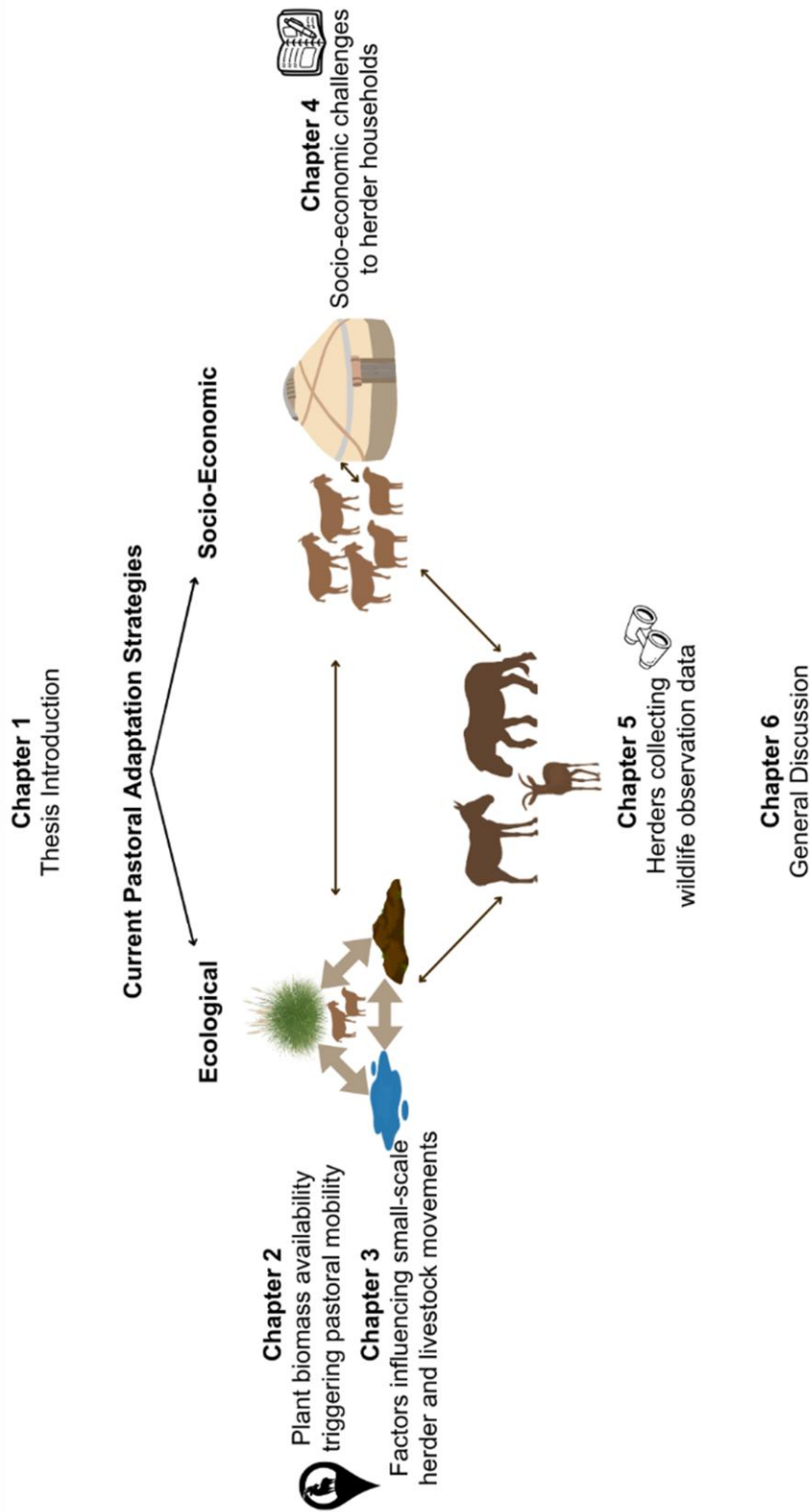


Figure 1.7: This figure illustrates the interconnections between current ecological and socio-economic pastoral adaptation strategies in the Great Gobi B Strictly Protected Area, Mongolia. Chapters One and Six provide the conceptual and concluding frameworks of the thesis. Chapters Two and Three examine ecological adaptation strategies, while Chapter Four focuses on socio-economic approaches. Chapter Five presents a practical example of local pastoral involvement in conservation efforts. Arrows indicate the thematic and analytical linkages between the individual chapters.

Chapter 2 Moving Toward the Greener Side: Environmental Aspects Guiding Pastoral Mobility and Impacting Vegetation in the Dzungarian Gobi, Mongolia



Figure 2.1: Mongolian yurt of a herder family in the Great Gobi B Strictly Protected Area in Mongolia (Photo by Lena Michler, 2018)

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Moving Toward the Greener Side: Environmental Aspects Guiding Pastoral Mobility and Impacting Vegetation in the Dzungarian Gobi, Mongolia

Lena M. Michler¹, Petra Kaczensky^{2,3}, Jane F. Ploechl¹, Daginnas Batsukh⁴, Sabine A. Baumgartner¹, Bayarmaa Battogtokh⁵, Anna C. Treydte^{1,6}

¹ Department of Ecology of Tropical Agricultural Systems (490f), Institute of Agricultural Sciences in the Tropics (Hans-Ruthenberg-Institute), University of Hohenheim, Stuttgart, Germany

² Department of Forestry and Wildlife, Faculty of Applied Ecology, Agricultural Sciences and Biotechnology, Inland Norway University of Applied Sciences, Norway

³ Research Institute of Wildlife Ecology, University of Veterinary Medicine, Vienna, Austria

⁴ School of Agroecology and Business, Mongolian University of Life Sciences, Darkhan, Mongolia

⁵ Research Institute for Animal Husbandry, Mongolian University of Life Sciences, Ulaanbaatar, Mongolia

⁶ Department of Physical Geography, Stockholm University, Stockholm, Sweden

2.1 Abstract

Livestock grazing often intensifies around herder camps, which can lead to degradation, particularly in arid areas, where vegetation is scarce. In Mongolia, nomadic herders have covered long distances between camps and changed camps regularly for centuries. However, changing socioeconomics, rising livestock numbers, and climatic change have led to growing concerns over rangeland health. To understand travel mobility and livestock grazing patterns, we combined Global Positioning System tracking data of goats, remotely sensing pasture productivity, and ground-based vegetation characteristics in the Great Gobi B Strictly Protected Area, Mongolia. We assessed herder preferences for camp selection, followed 19 livestock herds over 20 months, determined use and nutrient contents of the most dominant plant communities, and estimated plant species richness, vegetation cover, and biomass within different grazing radii around camps. Biomass availability was key for herder decisions to move camps, but in winter, other factors like shelter from wind were more important. Camps were mainly located in *Stipa* spp. communities, agreeing with herder preferences for this highly nutritious species, and its dominance around camps. Herders changed their camp locations on average 9 times yearly, with a maximum distance of 70–123 km between summer and winter camps, and an average visitation period of 25–49 d per camp, depending on season. Small livestock spent > 13–17 h daily within a radius of 100 m from camp, and livestock use intensity decreased steeply with distance from camp but was remarkably similar around spring, autumn, and winter camps on the Gobi plains. However, we found little evidence for a corresponding gradient in plant species richness, biomass, and cover on the Gobi plains. The high mobility of local herders and the overriding impact of precipitation on pasture dynamics contribute to a sustainable vegetation offtake by livestock in the nonequilibrium rangelands of the Dzungarian Gobi.

Keywords: *Enhanced vegetation index, GPS collars, Mobility, Nomadic herding tradition, Protected area Rangeland*

2.2 Introduction

Pastoralism is the main income generation activity of local communities in many arid and semi-arid regions that are unsuitable for agriculture (Hogg, 1992). However, globally increasing livestock numbers (Thornton, 2010), in combination with climate change (Christensen et al., 2004; Crook et al., 2020), have led to growing concern over degradation and loss of rangeland. Pastoralism is often practiced in areas with high biodiversity but overall low biomass productivity (Berzborn & Solich, 2013). Mobility is a key strategy for herders worldwide to maintain adequate forage intake for livestock and distribute grazing pressure across the rangeland (Coughenour, 1991; Liao et al., 2017). This flexibility is of major importance in arid and semi-arid regions where forage availability and quality differs within and between years, mainly due to unpredictable precipitation (Le Hou  rou et al., 1988; Noy-Meir, 1973). However, this mobility is threatened by trends towards fewer camp moves and reduced walking distances by livestock (Jordan et al., 2016a; Tsvegemed et al., 2018).

Movement patterns of herders and their livestock are differentiated into broad- and fine-scale movements: (1) travel mobility describes the seasonal movements between camps, and (2) grazing mobility focuses on daily grazing patterns (Adriansen, 2008; Liao, 2018; Turner & Schlecht, 2019). Different grazing mobility models have been discussed in the literature suggesting an evenly distributed grazing pressure around herder camps (Homewood & Rodgers, 1991) or grazing gradients radiating away from settlements (Spencer, 1973) known as piosphere (Lange, 1969) or central-place model (Coppolillo, 2001). The area directly around the camps is often described as ‘sacrificed’ zone due to heavy and repeated use by livestock, followed by a ‘transition’ zone with decreasing grazing intensity radiating away from the camp towards areas which are rarely used for livestock grazing (Liao et al., 2017). ‘Sacrificed’ zones are characterized by heavy trampling, dung and urine depositions, and opportunistic grazing (Andrew, 1988; B. Hess et al., 2020). Grazing gradients might be weakened by large-scale travel mobility patterns and short duration of stay at single camps. Only few studies have investigated both large-scale and small-scale grazing patterns of livestock using GPS tracking devices (Adriansen & Nielsen, 2005; Butt et al., 2009; Jordan et al., 2016a).

Higher livestock numbers, and therefore higher grazing intensity, have been affiliated with lower plant species diversity, vegetation cover, and biomass (Lambin et al., 2001), particularly of herbaceous plants (Treydte et al., 2017), but also in woody communities (Chaideftou et al., 2008). The daily maximum walking distance and the time spent grazing at different distances from camp on the one hand can be expected to vary with forage availability and on the other

will determine grazing pressure (Coppolillo, 2000; Schlecht et al., 2004). This grazing distance is often determined by daily maximum distance from camp, grazing loop, or home range (Liao, 2018). However, few studies have investigated the recorded GPS locations as time spent by livestock per area (Coppolillo, 2001), and those studies often omit the importance of local socio-ecological herding strategies (Butt, 2010) such as local knowledge about livestock, climate and vegetation interactions (Fernandez-Gimenez, 2000).

Herders' traditional ecological knowledge (TEK) about grazing areas has been passed on for generations (Fernandez-Gimenez, 2000; Oba & Kaitira, 2006; Treydte et al., 2017), whereby herders characterize different pastures according to plant community, nutritional quality of plant species, and season in which the pastures are used (Fernandez-Gimenez, 2000). Combining travel and grazing mobility with vegetation resource availability on the ground is crucial to avoid too general conclusions and abstractions (Turner & Schlecht, 2019). Rangeland studies have mainly focused on forage availability in terms of biomass and vegetation cover (Ahlborn et al., 2020; Sasaki, Okayasu, Shirato, et al., 2008; Sternberg, 2012) whereas few studies have included nutritional values of pastures across seasons (Beher, 2014).

In Mongolia, 80% of the 150 million ha land is used for extensive livestock grazing (Angerer et al., 2008), and pastoralism is the main livelihood for around 240,000 herder households (Mongolian Statistical Information Service, 2023). The rapid increase in livestock numbers over the last 30 years (Lkhagvadorj et al., 2013a) has resulted in a record number of over 70 million animals in Mongolia in 2019 (Mongolian Statistical Information Service, 2023). This increase in livestock numbers, especially goats, is often quoted as cause for rangeland degradation (Hilker et al., 2014; Liu et al., 2013). However, the negative impacts of high livestock numbers on the degradation risk of rangelands risk is highly debated especially where precipitation is scarce (Addison et al., 2012).

In the arid Gobi regions of southern Mongolia, temporal and spatial variability of precipitation leads to a non-equilibrium system where precipitation is the key driver for pasture productivity and subsequently ungulate numbers (Fernandez-Gimenez and Allen-Diaz, 1999; von Wehrden et al., 2012). Variability in precipitation forces herders to move (Pfeiffer et al., 2020) and extreme weather result in mass-die offs which “downregulate” livestock numbers allowing vegetation to recover; non-equilibrium rangelands under a traditional grazing regime are therefore considered to be rather resilient to degradation by several authors (Cheng et al., 2011; Wesche et al., 2010; Wesche & Retzer, 2005). Herders in the Gobi are known for their longer travel distances and more frequent camp shifts as compared to herders in other parts of Mongolia

(Reading et al., 2006). This mobility and spatio-temporal flexibility allows them to react to variation in pasture availability within and between years (Niamir-Fuller, 1999) but has rarely been tracked, especially in arid systems.

Until recently, herder and livestock mobility has been primarily studied through interview data in Mongolia (Lkhagvadorj et al., 2013a; Ono & Ishikawa, 2020). Therefore, very little day-to-day data on seasonal movements or livestock use intensity around seasonal camps is available. Furthermore, only few studies have looked over different spatial scales in Mongolia (Teickner et al., 2020) or interlinked social (Fernández-Giménez et al., 2018; Fernández-Giménez & Febre, 2006; Mocellin & Foggin, 2008), and ecological (Fernandez-Gimenez, 2000; Lang et al., 2020; Narantsetseg et al., 2018) disciplines. To close this knowledge gap to better understand drivers behind herder travel mobility and assess the impact of grazing mobility around herder camps, we chose an integrative data analysis framework, combining GPS data of livestock herds, remote sensing products characterizing pasture at the landscape scale, vegetation assessments at the local scale, and complemented those data with traditional ecological knowledge. With this approach we aimed to answer the following questions:

- 1) What are the key determining factors for travel mobility and camp selection of herders across seasons? How do herders' travel mobility patterns and camp use duration vary between seasons?*
- 2) Do herders choose specific plant communities for their camps? Is this selection consistent with forage quality and availability of respective plant communities?*
- 3) What is the grazing intensity around herder camps and how does it vary with distance from camp and season? Is the grazing intensity reflected in the vegetation around herder camps?*

Our study pinpoints travel and grazing mobility patterns and combines those with in-depth vegetation analysis joined with herder perspectives to help pastureland management within a protected area.

2.3 Material and Methods

2.3.1 Study area

The research was conducted in the Great Gobi B Strictly Protected Area (SPA) in south-western Mongolia from 2018 to 2020. The Great Gobi B SPA was established in 1975, stretching over $\approx 9,000 \text{ km}^2$ of semideserts and desert-steppes (Kaczensky et al., 2004b) and was recently extended to $\approx 18,000 \text{ km}^2$ (Sansarbayar, 2019) covering similar steppe plant communities. The

Great Gobi B SPA is part of the Dzungarian Gobi, bordering China in the South along the Takhin Shar Naruu Mountains and framed by the Altai Mountains in the North (Kaczensky et al., 2008). The international border is fenced, but the remainder of the protected area is not (Kaczensky et al., 2008). The Great Gobi B SPA is registered as IUCN category Ib (UNEP-WCMC, 2022) with a core, limited-use, and buffer zone. Elevations are between 1 000 to 2 840 masl, with plains towards the East and rolling hills in the West. The climate is continental, characterized by long cold winters (with average monthly of 4°C to -20°C between October and April), short hot summers (with temperatures of 14°C - 19°C between May and September) and very dry (with average precipitation of 96 mm per year) and falls into the non-equilibrium zone (von Wehrden et al., 2012). Weather data (hourly temperature (°C) and rainfall (mm)) have been recorded since 2013 with a HOBO weather station at the protected area administration camp (45°32'19.20"N 93°39'4.02"E), Takhiin Tal. During our study period, summer rains peaked in June, but varied over the main study duration in 2018 and 2019 both in timing and overall amount (Figure 2.2).

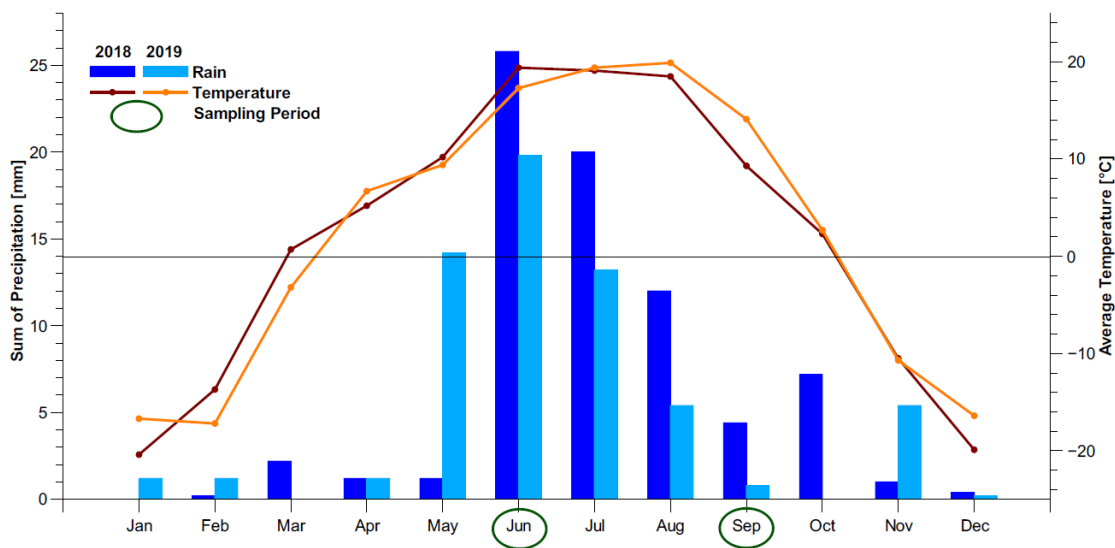


Figure 2.2: Average monthly temperature collected with a HOBO weather station at Takhiin Tal research station in the years 2018-2019. Green circles mark the months of vegetation sampling period at the beginning and end of the growing season, respectively.

The Great Gobi B SPA is part of the central Asian flora region with shallow and poorly developed soils, and is dominated by semi-desert and desert-steppe vegetation with characteristic plants adapted to aridity like *Haloxylon ammodendron*, *Ephedra przewalskii*, *Reaumuria soongarica* und *Anabasis brevifolia*. In areas where desert-steppe is found, Poaceae like *Stipa* spp. and Asteraceae like *Artemisia* spp. and *Ajania* spp. dominate (von Wehrden et al., 2006). The

Dzungarian Gobi has a relatively high plant biodiversity for a desert, hosting around 717 plant species (Gubanov, 1996).

Around 130 herder families (personal com., Ganbaatar Oyunsaikhan, director of the Great Gobi B SPA, 2018 and 2019) and their livestock use the Great Gobi B SPA in winter and on their way to and from the summer pastures on the alpine meadows of the Altai mountain range. Herders spend about nine months inside or adjacent to the Great Gobi B SPA (personal com., Ganbaatar Oyunsaikhan, director of the Great Gobi B SPA, 2018 and 2019). These herder families have to register their winter camps at the district level and are mostly granted grazing rights for around 15 years, after which the contract can be renewed (personal com., Mr. Myatav, local governor, 2019). Based on old agreements, herders are allowed to use camp sites within the limited-use and buffer zones, but are only allowed to move across the core zone quickly during their travel movements.

Most common livestock in the region are, in decreasing order of abundance, goats (*Capra aegagrus hircus*), sheep (*Ovis aries*), cows (*Bos taurus turano mongolicus*), horses (*Equus ferus caballus*), camels (*Camelus bactrianus*) and yaks (*Bos grunniens*; Kaczensky et al., 2008). Only sheep and goats (“small livestock”) are tended in mixed herds on a daily basis while large livestock is only checked daily or weekly and may even go unaccompanied over extended periods (Kaczensky et al. 2008, personal observation). Our study focussed on mixed livestock herds consisting of sheep and goats because they provide the most important source of income for local herders and are by far the most numerous livestock species (Mongolian Statistical Information Service, 2023).

2.3.2 Herder movement decisions

To understand how herders choose their camps we conducted three focus group interviews with a total of 36 local herders (11 women and 25 men), in November 2019. The focus group meetings took place at three different herder families’ camps, were led by a moderator and assistant interpreting the discussion, and each lasted between two and three hours (Krueger, 2014). Prior to the focus group discussions, we informed participants about the research aim and obtained consent through participants signatures. Participants were divided into subgroups to discuss questions about movement decisions and the decision-making process behind camp selection, when and why to move. Participants further discussed about rangeland plants most relevant and preferred by livestock. Subgroups agreed on the most favourable and nutritious plant species for each livestock species and season, and subsequently presented their results after mutual consent to the whole group. Notes were taken simultaneously in Mongolian and English. We

analysed the focus group interview data based on the *keywords-in-context* method as described by Onwuegbuzie et al. (2009). Herders named those plant species indicating good grazing sites and we subsequently related this information with the plant species we recorded around the herder camps.

2.3.3 Livestock movement patterns

To document travel and grazing mobility (Figure 2.3), we equipped one healthy, adult male goat each in 19 different livestock herds with a lightweight GPS collar (CatLog Gen2, Perthold Engineering LLC, Dallas, USA). Goats were chosen as representative animal species for all small livestock herds as the GPS devices fitted the goats body better than that of sheep. Of the 19 tracked livestock herds, eleven used the pastures of the Eastern part of the Great Gobi B SPA and eight of the Western part. However, we combined the analyses of all livestock herds, except when we reported the maximum distances between summer and winter camps. We programmed the GPS units to record a position at 30-min intervals between 7:00 and 22:00 hrs and pause the remainder of the night to save battery life, based on herder information that small livestock sleeps in the camp during this time. Collars were deployed over a 20-mo period from end of August 2018 to beginning of May 2020 (see Table A1, Figure A1, Figure A2 in the appendix) and collected on average 16,541 GPS locations per goat. The data set was corrected for outliers, stationary periods, and missing values caused by technical issues with the GPS devices or temporary removals of GPS devices by herders.

Based on the GPS tracking data, we visually identified camp locations in the middle of dense clusters of GPS points and movement paths returning to a specific location in QGIS (2.18.18); in many cases, camp location could be confirmed on the Google satellite image by the presence of a dark dung circle or man-made structures like stone corrals. We defined camps as “herder camps” when used for >7 days and “transition camps” when used ≤ 7 days, mainly used as short stop-over locations during camp moves (personal com., Ganbaatar Oyunsai Khan, director of the Great Gobi B SPA, 2018 and 2019). We classified the herder camps based on the date of use and location into “summer” (June to August), “intermediate” (March to May (spring) and September to November (autumn)), and “winter” camps (December and February). To understand grazing intensity by season and distance from camp (adapted from Coppolillo, 2001), we calculated the time GPS tagged goats spent at different distance radii of 100, 500, 1,000, and 5,000 m from the camp (the time GPS units paused at night was added to the 100 m radius). Distance categories for grazing intensity corresponded with the location of our vegetation assessment plots. We subsequently determined grazing intensity, first by calculating the hours spent per ha

in each distance radius to account for the difference in available grazing area and then multiplied the value by the average number of days herders stayed at different seasonal camps to compare livestock use intensity among seasonal camps. Livestock use intensity can be assumed to correlate with grazing intensity, and entails trampling, and nutrient intake via urination and defecation.

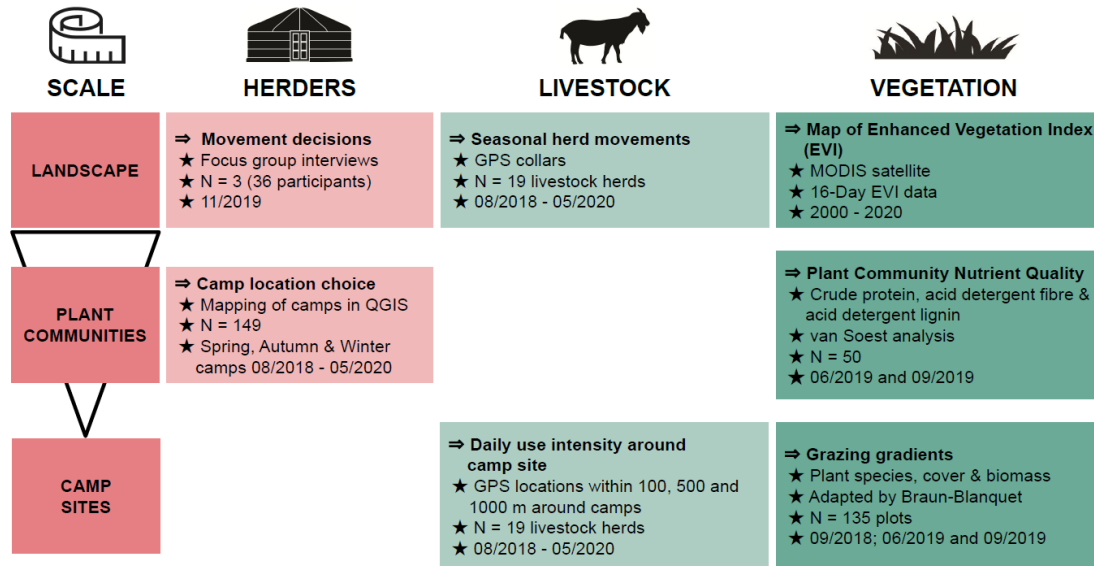


Figure 2.3: Schematic graph of data collection and analysis from 2018 until 2020 in the Great Gobi B, Mongolia. The figure illustrates how we investigated travel and grazing mobility with various methods at different scales and related it to the vegetation.

2.3.4 Vegetation assessments

Enhanced vegetation index as proxy for biomass

To estimate biomass availability at the landscape scale, we used the EVI (enhanced vegetation index) as a proxy, which is sensitive to spatial and temporal variations in biomass productivity, especially in areas with high soil exposure (Garrouette et al., 2016; Huete et al., 2002; Kawamura et al., 2005). We processed a 20-year time series (2000 - 2020) of the EVI in Google Earth Engine using the Terra Moderate Resolution Imaging Spectroradiometer layers (MODIS; MOD13Q1; Version 6), available at 16-day intervals (Didan, 2015; Paltsyn et al., 2019). We calculated the annual mean EVI for the vegetation period (May to September) at 250 m resolution for the entire Great Gobi B SPA as a baseline value and within a radius of 1,000 m around 187 seasonal herder camps identified from tracking data of GPS collared goats (Figure A3 in the appendix). During spring and autumn, herders often used the same camps; therefore, we combined these camps as ‘intermediate’ camps for this analysis. We additionally produced a

map visualising the average EVI over the entire 20-year period to visualize the underlying productivity gradients responsible for the seasonal movements.

Plant community nutrient quality of herder camps

We obtained the plant community type at each herder camp location from a digital vegetation map (von Wehrden et al. 2006). To assess forage quality in the five most dominant plant communities (von Wehrden et al., 2006), we collected mixed biomass samples in the beginning and end of the growing season (June 2019; September 2019). The five plant communities sampled were: 1) grasslands dominated by *Stipa* spp., and shrublands dominated by 2) *Caragana* spp., 3) *Nanophyton erinaceum*, 4) *Reaumuria soongorica* and 5) *Haloxylon ammodendron* (von Wehrden et al., 2006). We randomly selected five sites within each plant community on the ground and established two 10 x 10 m² plots within a distance of 100 m. Within each plot, we randomly sampled one 1 m² subplot by cutting all herbs and grasses to 1 cm above ground level. In total, we collected 10 samples per vegetation community, summing up to 50 plant community samples. We oven-dried the mixed samples at 60°C for 48 h, ground them and analysed them for crude protein (CP), acid detergent fibre (ADF) and acid detergent lignin (ADL) according to (Van Soest et al., 1991) as indicators for forage quality in the laboratory of the Mongolian University of Applied Life Sciences, Ulaanbaatar, Mongolia.

Grazing gradients around herder camps

We assessed vegetation characteristics around 45 herder camps (15 winter, 15 spring and 15 autumn camps) in the Eastern part of the protected area. We collected data on the same plots twice at the end (September 2018 and 2019) and once at the start of the growing season (June 2019). We walked transects in a North – South direction away from each camp and sampled vegetation within quadrats of 10 x 10 m² at 100 m, 500 m, and 1,000 m distance intervals (N = 135). We started the transects at the point where the vegetation-free ‘sacrifice zone’ (B. Hess et al., 2020) around the herder camps stopped, i.e., beyond a radius of 25 m, to avoid any potential bias through intense trampling or camp / housing impacts. In each quadrat, we identified and counted all individual plant species using Tungalag and Boldgiv (2016) and Jigjidsuren and Johnson (2003) to identify plant species richness and estimated species cover visually in % (Kent & Coker, 1992). Where species identification was difficult, we took photographs and collected herbarium samples for species determination by botanists from the National University of Mongolia (NUM). We harvested biomass samples within two randomly selected subplots (1 m²) within each 10 m² plot with common pruning shears and sorted them into the plant

groups “grasses”, “annual forbs” and “perennial forbs”, “subshrubs”, and “shrubs” adapted from Jamsranjav et al. (2018). This resulted in a total of 388 biomass samples collected on 90 subplots. All samples were stored in labelled paper bags and dried in the shadow until arrival in the laboratory of the Mongolian University of Applied Life Sciences, Ulaanbaatar, Mongolia. There, samples were dried at 60°C for 48 h in a common drying oven and weighed for dry matter (DM) content to calculate biomass·m⁻² (Jamsranjav et al., 2018).

2.3.5 Statistical analysis

GPS data was analysed with R software version R-4.0.3, using the ‘car’ package (Fox & Weisberg, 2019). We compared grazing intensity (hours·ha⁻¹ by average seasonal camp use in days) with a type III two-way ANOVA to identify differences between distance radii 100 m, 500 m, 1,000 m, and 5,000 m around different camp types (spring, summer, autumn and winter), and interaction effects between distance radii and camp types.

Forage quality parameters were compared for differences between plant community type, season and interaction effects in SPSS version 25 (IBM SPSS Inc., Chicago, USA) using type III two-way ANOVAs. The Levene test was applied for homogeneity of variances plus visual assessment of normal distribution of the residuals from scatter plots and histograms. Tukey post-hoc test was used for pairwise comparisons.

Vegetation data was analysed with SAS/STAT software version 9.4 (SAS Institute Inc. 2016). We compared plant species richness, vegetation cover and biomass data with a linear general mixed model to identify differences across distance classes around camps and sampling month (September 2018 and 2019: end of growing season, and June 2019: beginning of growing season). To account for spatial and temporal repeated measures we applied the anisotropic power model (Piepho et al., 2004). To meet the assumptions of homogeneity of variance and normality, data was transformed if necessary. Percentage data (vegetation cover) was arcsine-transformed and biomass data was log- or square root-transformed. The outcomes were plotted with Qtiplot (IonDev SRL software, version 5.12.8) showing means and standard deviation or errors of the un-transformed data. For all statistical analyses, significance levels were set at $P \leq 0.05$.

2.4 Results

2.4.1 Herder travel mobility decisions and camp selections in different seasons

We recorded a total of 187 unique camp locations, of which some were used repeatedly by herders during our 20 month tracking period totalling up to 250 camps, and additional 166

transition camps. Maximum travel distances between winter camps in the Gobi and summer camps in the Altai mountains differed between herders in the eastern and western part of Great Gobi B SPA due to the NW to SE orientation of the Altai range (Figure 2.4).

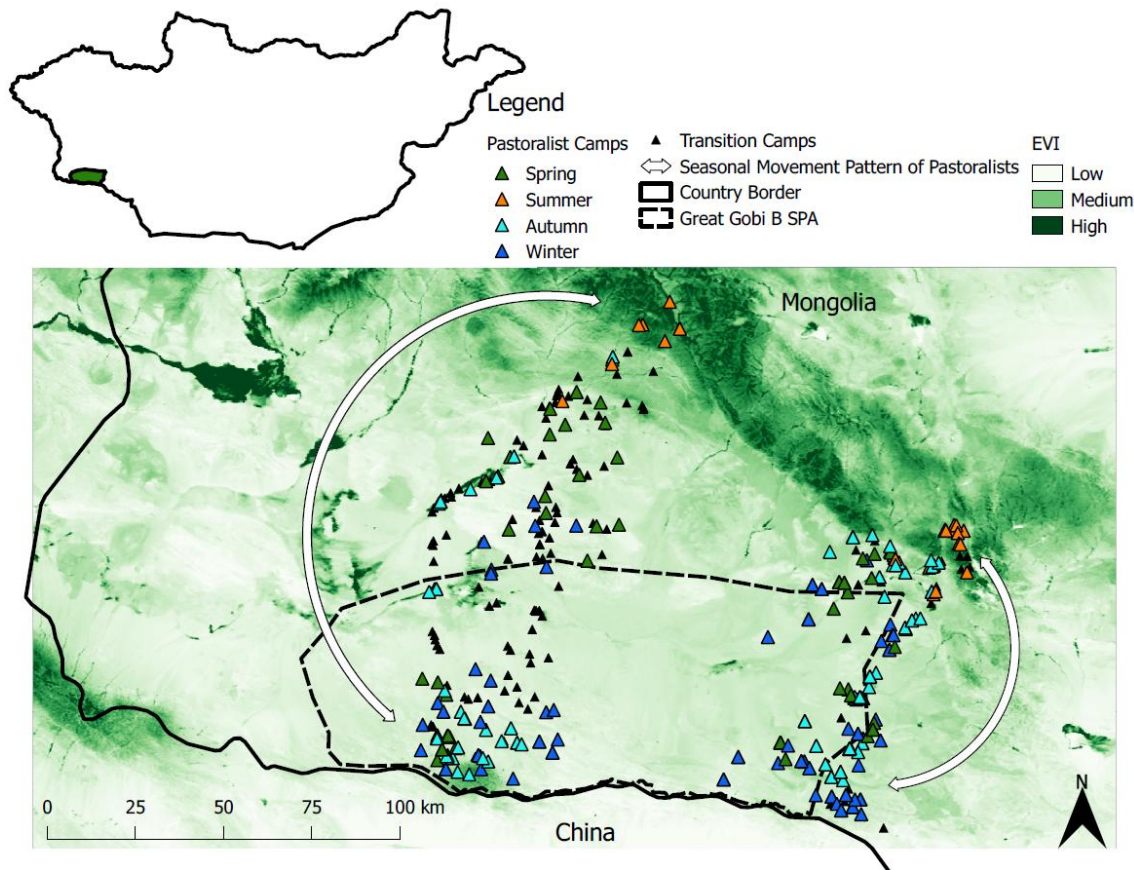


Figure 2.4: Location of 187 seasonal herder camps and 160 transition camps occupied by 19 herder families from August 2018 until May 2020 in the Great Gobi B SPA, Mongolia. The background shows the 20-year average of biomass availability using the Enhanced Vegetation Index (EVI) as proxy. *White arrows* illustrate the herders' seasonal movements between summer camps on alpine pastures in the Altai mountain range and winter camps in the Gobi.

The mean ($\pm$ SD) annual distance between the northernmost summer camp and southernmost winter camp averaged 123 ($\pm$ 20) km in the west and 70 ($\pm$ 21) km in the east (Fig. 3). Herders changed their camp locations on average 9 ($\pm$ 2) times per year, most frequently making use of 2 different summer and winter camps each, 2 spring and 3 autumn camps. Herders stayed 3-4 weeks in spring and autumn camps, and between 6-7 weeks in summer and winter camps (Table 2.1). Biomass estimates for the growing season were 2.5 times higher around summer camps in the Altai mountains (mean EVI: 1,400 $\pm$ 328), slightly higher at intermediate (spring and autumn) camps (mean EVI: 739 $\pm$ 119), and around the same at winter camps (mean EVI: 584 $\pm$ 92) compared to the average over the entire Great Gobi B (mean EVI: 581 $\pm$ 61; Figure 2.5).

Table 2.1: Average number of camps per season used over a 20 month period and duration of stay calculated for 250 seasonal herder camps (including repeated camp use) and average number of 166 seasonal transition camps used by 19 herder families in and around the Great Gobi B SPA in Mongolia. Average numbers were adapted to different sample sizes according to missing values in each season. Duration of stay was only calculated for fixed camps. Data are based on 314,275 GPS locations during the monitoring period between end of August 2018 and beginning of May 2020.

	Spring	Summer	Autumn	Winter
No. of camps	2.3 ± 1.2	1.6 ± 0.5	3.1 ± 0.7	2.2 ± 0.7
No. of transition camps	2.1 ± 2.1	1.1 ± 1.1	1.7 ± 2.1	1.1 ± 1.3
Duration of stay (days)	28.7 ± 15.7	42.6 ± 21.6	24.6 ± 11.2	49.1 ± 29.5

The decision criteria of herder families were reflected well by the remote sensing data as herders identified pasture productivity as the key variable for camp selection in summer, spring and autumn. Further, our interviews revealed that for the intermediate camps in spring, herders preferred areas of early snow melt and green-up, found in the Gobi plains close to springs and oasis. These sites ideally were sheltered from the wind by natural topography or man-made corrals. In summer, herders preferred areas with lush, nutritious vegetation, access to rivers, cooler temperatures and few biting insects, usually found in the Altai mountains. Herders considered the cooler climate, and grass dominated mountain meadows close to the numerous mountain streams as very important to allow livestock to gain weight. For the intermediate camps in autumn, herders preferred areas with nutritious vegetation close to water sources, often near or at spring camps, until the first snow fall. In winter, herders preferred sheltered areas with moderate snow depth, allowing livestock easy access to forage and satisfying water requirements via snow consumption.

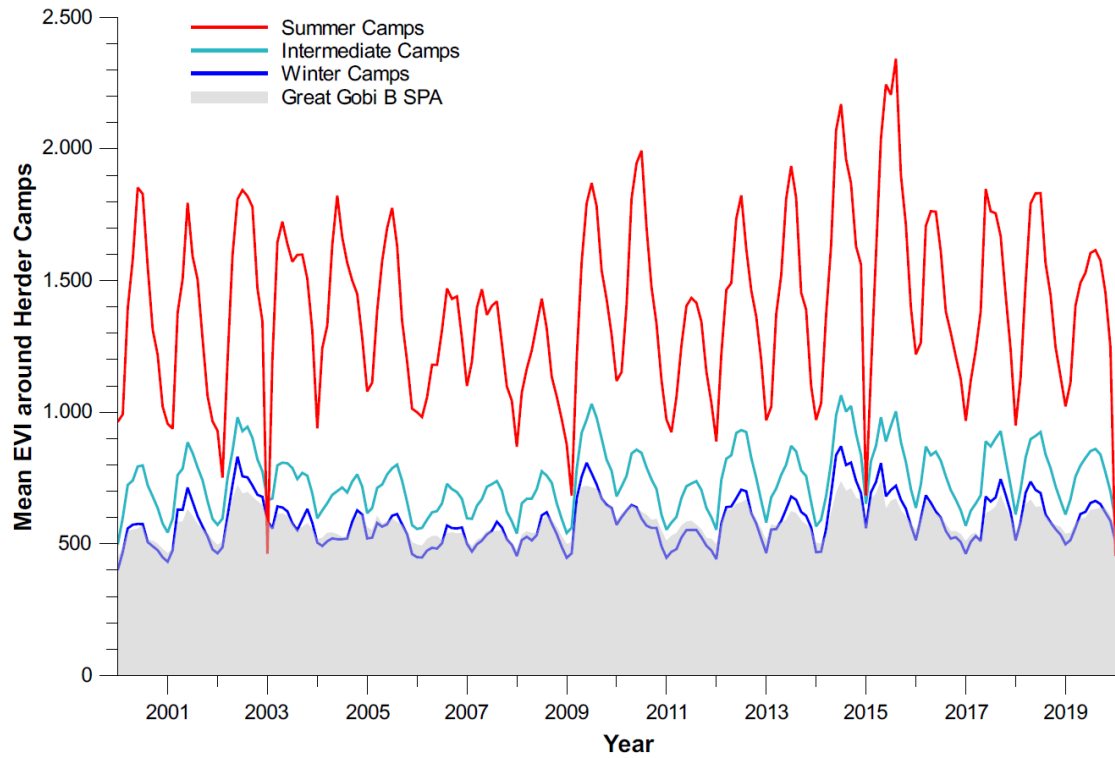


Figure 2.5: Mean EVI from 2000 until 2020 in a 1,000 m radius around 187 seasonal herder camps in and around the Great Gobi B SPA in Mongolia. Only the growing season, from May to September, was considered. The average for the entire Great Gobi B SPA is shown as a shaded grey area for comparison.

2.4.2 Camp selection in different plant communities based on forage quality

Local herders identified *Stipa* grasslands and specifically *Stipa gobica*, *Stipa glareosa* and *Al-lium mongolicum* as the most important forage plants throughout all seasons (Table 2.2) whereas the plant communities *Reaumuria soongorica* and *Caragana* spp. were mainly important for livestock during the winter months. This preference was reflected in the location of herder camps based on GPS data, where the majority of spring, autumn and winter camps (63%) were located in *Stipa* spp. communities, followed by mountain meadow, and *Haloxylon am-mondendron* communities (Table 2.2). The herders' preference also agreed with forage quality of the different plant communities, whereby we assumed that high CP combined with low fibre contents (ADF and ADL) indicated good forage quality (Newman et al., 2009). *Stipa* spp. communities showed moderate CP values, but lowest ADF and ADL values compared to the other plant communities, indicating highest palatability (Figure 2.6). Plant communities differed significantly in their CP contents ($F_{4,38} = 4.74$; $P = 0.003$; Fig. 2.6) and there was an interaction effect between plant communities and sampling month ($F_{4,38} = 3.45$; $P = 0.017$). CP contents were on average 23% higher in June 2019 compared to September 2019 for four out of five

plant communities ($F_{1,38} = 20.89$; $P = 0.001$). ADF contents differed significantly among plant communities ($F_{4,38} = 7.06$; $P \leq 0.001$), and were 13% lower in June 2019 than in September 2019 ($F_{1,38} = 14.75$; $P \leq 0.001$). The ADL averages differed significantly between plant communities ($F_{4,38} = 9.76$; $P \leq 0.001$) and highest seasonal differences ($F_{1,38} = 33.56$; $P \leq 0.001$) were observed in ADL, with 29% lower values in June 2019 compared to September 2019 (Figure 2.6).

Table 2.2: Herder camp locations across different plant communities in the Great Gobi B SPA in Mongolia. Vegetation at summer camps were not assessed as they were located outside the protected area (Figure 2.4). Plant communities are based on the vegetation map by (von Wehrden et al., 2006). Genera highlighted with asterisks were used to mark plant communities, which were sampled for forage analysis in June and September 2019 at five sites within each plant community (N = 50) (see Figure 2.6). Calculations are based on total N = 200.

Plant communities	Spring Camps (n = 44)	Autumn Camps (n = 83)	Winter Camps (n = 73)
<i>Stipa</i> spp.**	24	52	50
<i>Haloxylon am-</i> <i>mondendron</i> **	5	10	4
<i>Mountain meadows</i>	7	10	13
<i>Achnatherum</i> spp.	4	7	2
<i>Nitraria</i> spp.	1	2	3
<i>Nanophyton</i> spp.**	1	0	0
<i>Salt meadows</i>	1	0	0
<i>Juniper</i> shrubs	0	2	1
<i>Reaumuria soongarica</i> **	1	0	0
<i>Caragana</i> spp.**	0	0	0

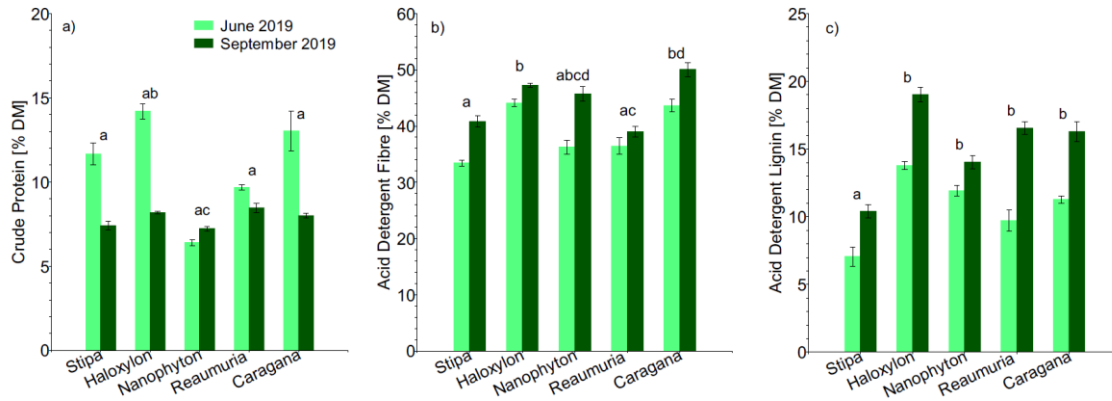


Figure 2.6: Mean ($\pm$ standard error) nutritional values expressed as percentage of dry matter of selected plant communities common in Great Gobi B SPA in Mongolia. a) Crude protein (CP), b) Acid detergent fibre (ADF), and c) Acid detergent lignin (ADL). Samples were collected in June and September 2019 (N = 50). Bars with the same letter are not significantly different at $\alpha = 0.05$ according to Tukey post-hoc test. Post-hoc test refers to differences between plant communities, not across seasons.

2.4.3 Livestock use intensity around herder camps and influence on vegetation

With an average visitation period of 49 days, herders stayed almost twice as long at winter camps compared to spring and autumn. Summer camps were used almost as long as winter camps (Table 2.1). Small livestock spent over 50% of time per day within a radius of 100 m around the camps, primarily resting. Consequently, use intensity of the rangeland at the different distance radii differed significantly by distance ($F_{3,984} = 548.71$; $P < 0.001$), but also by season ($F_{3,984} = 33.42$; $P < 0.001$), as well as their interaction ($F_{9,984} = 33.37$; $P < 0.001$). Use intensity (over the average visitation period) steeply decreased from 118-264 hours/ha at 0-100 m away from the camp, to 43-94 minutes at 101-500 m, to 9-18 minutes at 501-1000 m and to 1.1-2.3 minutes at 1001-5000 m. At winter camps, use intensity was twice as high around camp (0-100m), so that despite the much longer presence time, use intensity within the other distance zones was within the same values as for spring and autumn camps. At summer camps, use intensity tended to be higher in the 101-500 distance radius, compared to spring, autumn, and winter camps, potentially reflecting the much higher pasture productivity in the close vicinity of the camps at the alpine meadows (Table 2.3).

Table 2.3: Livestock presence as a proxy for use intensity at different distance radii away from the centre of 250 seasonal camps, in the Great Gobi B, Mongolia. Values were calculated taking into account the exclusive area of different distance radii. The average number of days herder families occupy camps during different seasons and are expressed as hours·ha⁻¹ over an average visitation period (see Table 2.1). N shown for each seasons corresponds to the total GPS points used for calculation.

Radius (m) [area (ha)]	Distance from camp centre			
	100 (3.1)	500 (74.4)	1000 (235.6)	5000 (2185.8)
Livestock use intensity (hours·ha ⁻¹ over an average visitation period) during camp occupation				
Spring (N = 51,105)	127.02 ± 67.52	0.78 ± 0.65	0.15 ± 0.09	0.03 ± 0.01
Summer (N = 32,160)	172.40 ± 86.56	1.57 ± 0.84	0.31 ± 0.14	0.04 ± 0.02
Autumn (N = 73,916)	117.89 ± 56.05	0.72 ± 0.49	0.15 ± 0.09	0.02 ± 0.01
Winter (N = 114,220)	263.95 ± 155.67	0.72 ± 0.50	0.21 ± 0.14	0.03 ± 0.02

Out of 47 different plant species found across all plots around herder camps, nine species were mentioned by herders as important forage plants for livestock (Table 4). Five genera/species, namely *Stipa* spp., *Artemisia* spp., *Allium mongolicum*, *Kraschennikovia ceratoides*, and *Anabasis brevifolia*, occurred on $\geq 50\%$ of all plots around herder camps. The first four of these species/genera were on the list of important forage plants by local herders (Table 2.4). Plant species richness was with 45 plant species generally low, averaging 7 species per plot, and did not differ significantly across distance categories ($F_{2,123} = 0.80$; $P = 0.45$), and no interaction effects between season and distance were found ($F_{4,123} = 0.188$; $P = 0.12$; Figure 2.7). However, plant species richness differed depending on sampling time ($F_{2,123} = 4.66$; $P = 0.01$), with slightly higher species richness in September 2018 and June 2019 compared to September 2019 ($P = 0.004$ and $P = 0.04$, respectively; Figure 2.7).

Plant cover averaged 14.0%, with 7.4% herbaceous (annual/perennial forbs and grasses), 4.1% subshrub and 2.5% shrub layer. Only the shrub layer significantly increased with increasing distance away from the camp ($F_{2,84} = 8.86$; $P < 0.001$), whereas there were no significant differences in the herbaceous ($F_{2,123} = 1.89$, $P = 0.16$) and the subshrub layer ($F_{2,84} = 0.10$; $P = 0.90$). Only the grass layer varied between sampling period, being higher in September 2018 compared to June 2019 and September 2019 ($F_{2,84} = 3.23$; $P = 0.05$; Figure 2.7).

Foliar biomass averaged 23.3 g·m⁻², with 8.7 g·m⁻² for the herbaceous, 13.4 g·m⁻² for the subshrub and 1.2 g·m⁻² for the shrub layer. Average ($\pm$ SE) total foliar biomass was highest in

September 2018 at 0-100 m around camp, but this pattern was not consistent across all three sampling periods and, hence, no significant differences were found among distance categories ($F_{2,84} = 0.26$; $P = 0.77$). Only the herbaceous layer biomass differed between sampling periods, being twice as high in September 2018 compared to June 2019 and September 2019 ($F_{2,42} = 2.56$; $P = 0.01$).

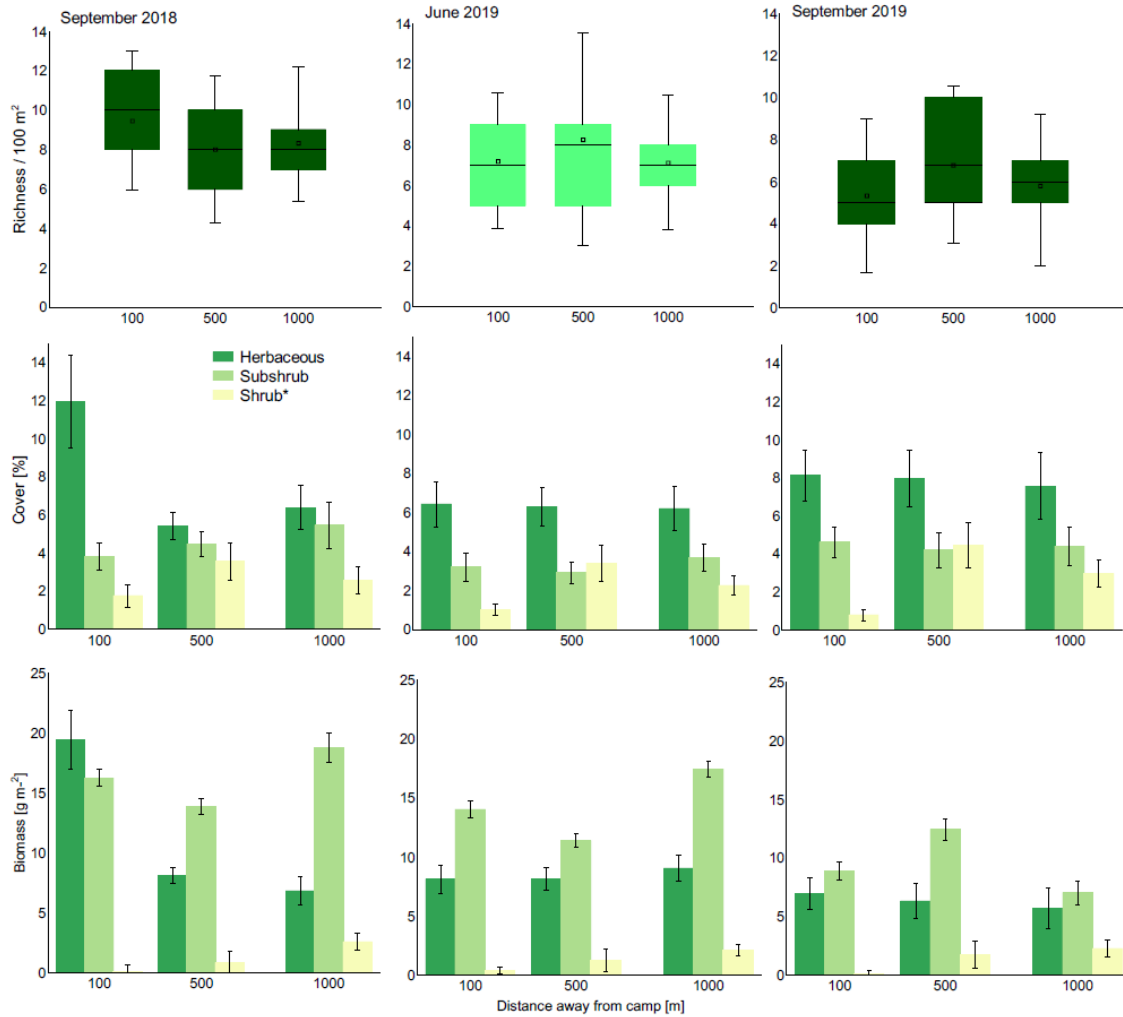


Figure 2.7: Vegetation characteristics at different distance intervals from the herder camps. Vegetation data around intermediate and winter camps ($N = 45$) in three different seasons (September 2018, June 2019, and September 2019) along gradients away from the camp (distance classes: 100 m, 500 m and 1,000 m). a) No of species (richness) counted per 100 m² are shown as boxplots. Ranges from 25% to 75% quartile show the mean (square inside boxes), median (line inside boxes) and whiskers indicate standard deviations. b) Mean ($\pm$ standard error) plant cover per 100 m² plot of herbaceous (grasses, annual and perennial forbs) plants, subshrubs and shrubs given in percentage. c) Mean ($\pm$ standard error) biomass per 100 m² plot of herbaceous (grasses, annual and perennial forbs) plants, subshrubs and shrubs given in gram per m² of dry matter. *Shrub biomass solely measured of the species *Ephedra przewalskii* and *Ephedra equisetina* Bunge.

2.5 Discussion

2.5.1 Herders' travel mobility patterns, camp selection and use duration varies across seasons

Our results highlighted that biomass availability was key for herders when leaving the desert-steppe region of the Great Gobi B SPA for higher elevation sites in summer, similar to travel mobility patterns by herders in the Altay region of China (Liao et al., 2014). Herders stated that in these mountain regions of our study site, nutritious vegetation, cooler climate, fewer biting insects and access to rivers and streams are available. The latter had also been identified as important by Ono and Ishikawa (2020). Traditionally, herders in Mongolia travel between spatially fixed winter (Lkhagvadorj et al., 2013a) and more flexible spring, summer, and autumn camps based on the availability of forage, water, and shelter from adverse environmental condition (Behnke et al., 2011). In our interviews, herders claimed that moving to spring camps was primarily motivated by early snow melt and sprouting of fresh vegetation, which we could also show through higher than average EVI values at these sites. Spring camp locations were mainly selected close to water, where green-up happens early and in sheltered areas to protect the new born livestock from extreme temperatures, which was also found by Behnke et al. (2011). Based on interviews, pastoralists selected autumn camps in areas with higher biomass availability for livestock to gain weight through high-quality forage before the winter months, similar to Behnke et al. (2011) in the steppes of Mongolia. While spring and autumn camps were changed more often in our study, being open for all herders without any registration requirement according to Ono and Ishikawa (2020), winter camps of fixed locations were officially allocated to individual herder families and often are marked by stone corrals (Lkhagvadorj et al., 2013a). For the winter camp selection, biomass availability was not the primary concern but rather other factors like shelter and availability of snow providing drinking water were key, according to our focus group interviews. We found that herders in the Great Gobi B SPA shifted their camps frequently, on average nine times per year. Some of the recorded camps were used twice or three times by herders during the monitoring period, especially the intermediate camps in spring and autumn. In summer, the hot Gobi plains were not used by herders and vegetation could recover. Our observed mobility of herders can strongly reduce vulnerability to forage shortage (Liao et al., 2014). Overall, we found that herders stayed longest at their winter camps, directly followed by summer camps, and shortest camp use in spring and autumn, similarly to results reported by Lkhagvadorj et al. (2013). In the Mongolian province of Bayankhongor, herders move only between three seasonal camps, stay on average six months at the

same winter camp, and some of the herder families do not move at all, due to socio-economic factors (Ahearn, 2018). The highly fluctuating resource availability in an arid region like the Great Gobi B SPA, in contrast, likely forces herders to move much more frequently compared to other arid regions globally: herders in South Africa rotate 2-4 times per year, mainly between summer and winter camps, following a dry and rainy season pattern (Michler et al., 2019; Samuels et al., 2019). In northern Pakistan, herders traditionally change between winter and summer pastures, while they change summer camps 2-3 times (Joshi et al., 2013). Our results showed that herders in the Dzungarian Gobi followed a four-season travel mobility pattern, similar to pastoralists in Western Mongolia and the Chinese Altay region (Joly et al., 2013; Liao et al., 2014), and we highlight that this might strongly contribute to a sustainable grazing management; not resulting in shifts in species composition or degradation. To maintain this ecological sustainability frequent camp shifts and extended travel mobility patterns should be encouraged, especially on pastures in and around protected areas.

2.5.2 Herders choose mainly *Stipa* spp. plant communities for their camp selection

In our study, herders classified different suitable habitats in the landscape as was expected based on their TEK to meet the nutritional needs (Meuret & Provenza, 2015). Our nutritional analyses confirmed the herders' TEK and showed that they selected the most nutritious grass communities composed of *Stipa* spp. as pastures for their mixed livestock herds, in line with findings by Fernandez-Gimenez (2000). We observed for these communities a lower CP and higher fibre contents with advancing growing period indicating decreasing digestibility, similar to findings in the Inner Mongolian steppe (Glindemann et al., 2009; Hao et al., 2013). Both vegetation quantity (Joly et al., 2013) and quality (Beher, 2014) seems to be important in arid environments. Our results confirm that herders choose grazing areas both high in biomass as well as high in nutritional quality. Herders in western Mongolia also were shown to prefer *Stipa* spp. for their summer pastures (Joly et al., 2013), with higher protein contents compared to other common Mongolian forage grasses (Jigjidsuren & Johnson, 2003). High nutritional quality of forage plants is often found on pastures with low forage availability, which is particularly important in arid regions (Shi et al., 2013) such as the Great Gobi B SPA. Hence, these ecosystems are highly fragile and livestock grazing must be maintained on a low and ecologically sustainable level, which does not result in degradation or a shift in plant species composition.

2.5.3 Limited evidence for grazing gradients around livestock camps in the Dzungarian Gobi is likely linked to the high mobility of local herders

Our results highlight highest livestock use intensities closer to camps, which generally is associated with high grazing intensity, trampling and nutrient input through urine and dung (Andrew, 1988; Hess et al., 2020; Sasaki et al., 2008a). While this long-term and high intensive grazing pressure around camps often leads to rangeland degradation, especially in arid regions (Vetter, 2005), we found limited evidence for signs of degradation around our camps. We found that livestock in the Great Gobi B SPA spent between 13 - 17 h of the day within 100 m around the camps and livestock grazed generally up to a 5 km radius around the camps. Similar to our findings, cattle herds in Cameroon had a grazing radius of around 4 km (Moritz et al., 2010), whereas the maximum distance of sheep and goat herds away from camps in Namaqualand of South Africa was around 2 km (Michler et al., 2019; Samuels et al., 2007). In winter, grazing pressure in the distance radii >100m was about the same as in spring and autumn, although livestock herds stayed almost twice as long at the winter camps. During winter livestock move and graze less because of shorter days and cold temperatures. Reduced grazing activity and walking distances during winter were also observed in yaks in the Qinghai-Tibetan plateau under extreme winter conditions (P. Liu et al., 2019), and forage intake by cattle in Montana, USA, was found to be reduced during winter (Adams et al., 1986). Research shows that herders who frequently change their camps with their livestock can make better use of pastures closer to their camps (Liao, 2018), compared to more sedentarized herders who have to extend their daily grazing distances when forage resources get scarce (Butt et al., 2009). It has to be stated that our study did not take the herd size and respective stocking rate into account, instead livestock use intensity was calculated as hours spent per ha on an average visitation period, used as a measure to relate to vegetation. Liao et al. (2014) reports a negative correlation between forage availability around winter camps and movement distance, especially in arid areas on overall lower altitudes, and a plant species shift towards more unpalatable annual and perennial forbs was observed around herder camps in the provinces of Mandalgobi and South Gobi of Mongolia by Sasaki et al. (2008b). However, in our study, we did not find grazing gradients for plant species richness and biomass across camps, and only shrub cover showed a significant increase further away from the camps. We acknowledge that our study only spanned over two years, within which recent long-term grazing effects on plant species richness and biomass are likely not visible, and we recommend regular pasture monitoring, which is crucial for long-term pasture health. In Namaqualand of South Africa, where grazing radii are smaller compared to the Great Gobi B SPA (Samuels et al., 2007), vegetation characteristics in the vicinity around

camps are negatively influenced due to intensive livestock use intensity (Michler et al., 2019). Our results are similar to other Mongolian studies that reported higher annual and perennial forb cover close to camps, corresponding to higher dung densities and, therefore, higher nutrient inputs (Jamsranjav et al., 2018; Sasaki et al., 2012; Sasaki, et al., 2008). As livestock spent around half of the day closest to the camps in our study, the nutrient inputs through dung and urine were most likely high, which favours certain plant species such as *Halogeton* spp., a salt-tolerant halophyte (Wang et al., 2015), poisonous to livestock (Li et al., 2021), which we often found directly adjacent to the herder camps. We highlight that potential plant species diversity shifts along the gradients is an important factor (Sasaki, and should be studied more in long-term studies in the Great Gobi B SPA.

Despite the large differences in livestock use intensity, which can be assumed to correlate with grazing intensity, trampling, and nutrient intake via urination and defecation, differences in plant species richness, biomass, and cover were minor across distance radii. However, particularly biomass and cover were more strongly related to monthly precipitation than distance categories. Moderate livestock grazing impacts have been seen in the Mongolian desert-steppe (Jamsranjav et al., 2018; Sasaki, et al., 2008; Wesche et al., 2010), but our findings suggest that precipitation might be the overriding factor influencing vegetation quality and quantity, similar to Fernandez-Gimenez and Allen-Diaz (1999) and Wesche et al. (2010). We base this assumption on the fact that the differences in biomass availability were greater between sampling periods than across distances away from camps. The non-equilibrium system of the Mongolian semi-deserts and deserts indicates that precipitation is influencing vegetation parameters much more than the grazing intensity (Fernández-Giménez & Allen-Diaz, 1999). However, our study only spanned two different years with high annual precipitation differences and calls out for more long-term vegetation monitoring in this region.

We also realized that overlaps between grazing sites of different herders occurred. Hence, the grazing intensity and pressure in the Great Gobi B SPA might be even higher than shown by our data. Still, in our study, no significant grazing gradients around herder camps were detected, indicating that travel and grazing mobility patterns by herders of the Great Gobi B SPA are well adapted to biomass availability.

In conclusion, our results showed that frequent changes, long travel distances, both between camps and around camps, are crucial for rangeland health. However, recent declines in pastoral mobility will negatively influence pastureland sustainability and results in land degradation (Liao et al., 2020). To maintain suitable pastures for livestock, and at the same time conserve

the flora and fauna in and around the Great Gobi B SPA, herders' mobility should be encouraged. Further, travel and grazing mobility patterns have to be monitored regularly, to maintain healthy rangelands, especially during forage shortage in dry periods.

2.6 Implication

The Great Gobi B SPA is a strictly protected area conserving biodiversity of flora and fauna, where in the limited-use and buffer zones, nomadic herders seasonally use the natural resources. Globally, pastoral movement patterns are declining, but in this system mobility is still practiced on a large scale with limited evidence for pasture degradation. However, considering the increasing livestock numbers and climate change in Mongolia, pasture management is crucial, and regular monitoring and control mechanisms of livestock use intensities in combination with vegetation assessments are needed. Our study only spanned over two years, within which slowly changing patterns in plant species richness or biomass due to grazing influence are likely not visible. Nevertheless, our combination of GPS tracking data, detailed vegetation analyses and herders' TEK highlights the importance of interdisciplinary work to understand pastureland management and vegetation responses, especially in a strictly protected area. Our study further shows that traditional pastoral systems can be practiced within protected areas, as long as mobility of herders is maintained and those patterns are monitored and regulated according to biomass availability, especially in times of forage shortage.

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Chapter 3 To move or not to move – factors influencing small-scale herder and livestock movements in the Dzungarian Gobi, Mongolia



Figure 3.1: A herder with a GPS collared goat in front of his small livestock herd on the summer pasture in the Altai mountains close to the Great Gobi B Strictly Protected Area in Mongolia (Photo by Lena Michler, 2018)

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To move or not to move—factors influencing small-scale herder and livestock movements in the Dzungarian Gobi, Mongolia

Lena M. Michler^{1,2}, Petra Kaczensky^{3,4}, Ganbaatar Oyunsaikhan⁵, Gundula S. Bartzke⁶, Olivier Devineau³, Anna C. Treydte^{1,7}

¹ Faculty of Agricultural Sciences, Institute of Agricultural Sciences in the Tropics (Hans-Ruthenberg-Institute), Department of Ecology of Tropical Agricultural Systems, University of Hohenheim, Stuttgart, Germany

² International Takhi Group (ITG), Alte Sihltalstrasse 38, 8135 Sihlwald, Switzerland

³ Faculty of Applied Ecology, Agricultural Sciences and Biotechnology, Department of Forestry and Wildlife, Inland Norway University of Applied Sciences, Campus Evenstad, Kopang, Norway

⁴ Research Institute of Wildlife Ecology, University of Veterinary Medicine, Vienna, Austria

⁵ Great Gobi B Strictly Protected Area Administration, Bugat Soum, Gobi-Altai, Mongolia

⁶ Faculty of Agricultural Sciences, Institute of Crop Science, Department of Biostatistics, University of Hohenheim, Stuttgart, Germany

⁷ Department of Physical Geography, Stockholm University, Stockholm, Sweden

3.1 Abstract

In Mongolia, where nomadic pastoralism is still practiced by around one-third of the population, increasing livestock numbers, socio-economic constraints and climate change raise concerns over rangeland health. Little empirical evidence explains what triggers camp moves of pastoralists in the Dzungarian Gobi in Mongolia, which factors influence grazing mobility around camps, and how altitudinal migration benefits small livestock. We combined GPS tracking data of 19 small livestock herds monitored from September 2018 to April 2020 with remotely sensed climate and environmental data. We used general linear-mixed models to analyse variables influencing camp use duration and daily mobility patterns. To understand the importance of the altitudinal migration, we compared climatic conditions along the elevation gradient and looked at seasonal body weight changes of small livestock. We found that available plant biomass and season best explained camp use duration. Daily walking distance and maximum distance from camp increased with camp use duration. Pasture time increased with increasing biomass and rising temperatures. We conclude that herders in the Dzungarian Gobi have optimized pasture use by reacting to changes in biomass availability at landscape and local scale, and by embracing altitudinal migration. Flexibility in grazing mobility seems to have enabled local herder communities to practise sustainable pasture use. Maintaining this mobility will most likely be the best strategy to deal with environmental change under the current climate change scenarios.

Keywords: *Altitudinal migration, Enhanced Vegetation Index, GPS tracking, Grazing mobility, Mongolia, Pastoralism*

3.2 Introduction

Mobility is a well adapted strategy of pastoralists and has been practiced globally for millennia to utilize fluctuating spatial and temporal forage and water availability (Coughenour, 1991; Hogg, 1992; Liao et al., 2017). However, socio-economic changes, globally increasing livestock numbers (Thornton, 2010) and climate change (Christensen et al., 2004; Crook et al., 2020; Godde et al., 2020) have drastically reduced herder mobility, thereby threatening rangeland health and reducing the resilience of local pastoral communities to environmental changes (FAO, 2023).

In Mongolia, 80% of the land is used for extensive grazing (Angerer et al., 2008), with about one third of Mongolia's population still practicing a pastoral livelihood strategy (Mongolian Statistical Information Service, 2023). However, herders no longer herd livestock for subsistence, but rather aim for a modern life in a market economy. As a consequence, livestock numbers in Mongolia have rapidly increased over the last 30 years (Lkhagvadorj et al., 2013a) and have reached record numbers of over 70 million livestock heads (Mongolian Statistical Information Service, 2023). In the Gobi regions, cashmere provides the main cash income for local herders and cashmere goats have become the dominating livestock (Berger et al., 2013). Grazing at high livestock intensities is seen as a main driver for rangeland degradation (Brown, 2020), potentially leading to ecological and cultural tipping points (Fernández-Giménez 2017). Consequently, understanding herd movements and herder's decisions about when and where to move livestock herds, are an important prerequisite for developing policy and management recommendations aiming to maintain rangeland resilience. In the Gobi region, changing climate in terms of increasing temperatures, altering rainfall patterns, and an increase in extreme winter events (Han et al., 2021) has already influenced herder livelihood strategies (Mijiddorj et al., 2019, 2020). In particular, younger herders and herders with livestock herds too small to maintain their livelihoods move to urban areas (Mijiddorj et al., 2019).

Herders in the Dzungarian Gobi, in SW Mongolia, are still highly mobile, changing seasonal camps on average 9 times per year, moving 70 to 125 km between most distant camps (Michler et al. 2022). Camp selection seems mostly linked to biomass availability during spring, summer and autumn, while during winter, additional requirements like sheltered places with access to snow influence site selection (Michler et al., 2022). Despite a steep gradient in grazing intensity around herder camps, there is limited evidence for a corresponding gradient in plant species richness, biomass, and cover on the Gobi plains (Michler et al., 2022). This suggests that herders leave their camps before the pasture is depleted. *We, therefore, expected that (1) herder's*

camp use duration primarily depends on biomass availability, and further tested if season and/or herd size also influenced the duration herders spent at single camps, assuming that larger herds remove more vegetation and deplete resources more quickly than smaller herds. During winter, when snow is the primary source of water for livestock and people, we expected that (2) moves into the winter camps are linked to the arrival of a lasting snow cover (Behnke et al., 2011).

Rangeland studies in Mongolia focused widely on how livestock impacts the ecological state of pastures, but little on how pasture biomass effects livestock mobility (Fernández-Giménez et al., 2018). Herders who change camp sites frequently can make use of high biomass availability close to their camps (Liao, 2018). More sedentary herders, on the other hand, have to lead their livestock further away in order not to deplete the pasture (Butt et al., 2009). *We hypothesized that (3) daily walking distance and daily maximum distance from camp are shorter when biomass availability is higher and herd size is smaller. Further, we expected (4) pasture time, daily walking distance, and maximum distance from camp to increase with increasing duration of camp use and larger herd size. We further expected that (5) pasture time, daily walking distance, and maximum distance from camp are primarily influenced by temperature on the Gobi plains and that the influence of temperature there is positive.* In summer, small livestock species of the temperate zones are sensitive to heat stress and will reduce their grazing activity when temperatures exceed the optimal temperature range for small livestock resulting in costs for thermoregulation (Joy et al., 2020; van Wettere et al., 2021). In winter, livestock faces the opposite challenge, and will save energy during cold periods, by moving less. *We also tested whether (6) a higher goat to sheep ratio has an influence on herd mobility, as goats walk more than sheep (Evangelou et al., 2014).* To illustrate daily and annual mobility patterns, we additionally, present data on small livestock speed as proxy for daily activity and total cumulative annual distance for overall annual mobility.

The situation in the Dzungarian Gobi is special relative to other parts of the Gobi, as local herders not only change camps within the Gobi plains, but additionally embark into an altitudinal migration to the Altai highlands in summer (Michler et al., 2022). In higher elevations, plant phenology is delayed and allows to access newly emerging, nutritious vegetation over a longer period (Albon & Langvatn, 1992). In the Gobi, extreme climatic conditions with an up to 80°C temperature difference between summer and winter (Brown 2020), and limited water availability, have far reaching consequences for seasonal pasture resources and livestock energy expenditure (Horie et al., 2023; Nardone et al., 2006), which ultimately impacts livestock fitness. We, therefore, used body weight as a proxy for small livestock fitness to understand the

influence of altitudinal grazing and the overall suitability of this grazing regime for small livestock production. *We (7) expected to see body weights of small livestock in the Dzungarian Gobi at the higher end of the spectrum typical for Mongolia.*

Our study used high-resolution GPS data of 19 herds monitored over 20 months and combined it with remotely sensed climate and environmental data. Our data provide information on how grazing mobility can combat environmental change caused by pasture depletion and degradation.

3.3 Material and Methods

3.3.1 Study area

Our study was conducted in the Great Gobi B Strictly Protected Area (SPA) in southwestern Mongolia from 2018 to 2020. Established in the year 1975, the protected area covered 9,000 km² at the beginning of the study, but was extended to twice the size in 2019 (Sansarbayer 2019; Figure 3.2). The Great Gobi B SPA is bordered by the Altai highlands in the North and by a chain of smaller mountains along the international border with China in the South, and belongs to the Dzungarian Gobi. The continental climate is characterized by temperature differences of up to 80°C with long, cold winters with temperatures as low as -40°C and short, hot summers with temperatures as high as +40°C and an average precipitation of 100 mm per year (Kaczensky et al., 2004a). In the desert-steppe, plants like *Stipa* spp., *Artemisia* spp. and *Ajania* spp. dominate, whereas in the desert *Haloxylon ammodendron*, *Ephedra przewalskii*, *Reaumuria soongarica*, and *Anabasis brevifolia* are most common (von Wehrden et al., 2006). Around 130 herder families and their livestock used the Great Gobi B SPA in its original size during the beginning of this study in 2018 (Michler et al., 2022). Herders use the pasture resources of the Great Gobi B SPA about 9 months during winter, spring and autumn and stay on the summer pastures on the alpine meadows of the Altai highlands outside the protected area for 3 months (Michler et al., 2022; Figure 3.2).

Most common livestock in the region are, in decreasing order of abundance, goats (*Capra aegagrus hircus*), sheep (*Ovis aries*), cattle (*Bos taurus turano mongolicus*), horses (*Equus ferus caballus*), camels (*Camelus bactrianus*), and yaks (*Bos grunniens*; (Kaczensky et al., 2008). Our study focused on small livestock (sheep and goats) that pastoralists tend in mixed herds on a daily basis. Herders kept mainly the native Mongolian goat and sheep breeds. Supplementary fodder was rarely provided and if so, only in very limited quantities during winter (personal

observation).

During our study, we used climate data (monthly mean temperature and precipitation) around each camp location. We used Google Earth Engine to access the Copernicus Climate Change Service available at 27,830-m resolution (Copernicus Climate Change Service (C3S), 2023). The climate regime at summer camps on the Altai highlands had higher rainfall, lower temperatures, and in summer maximum monthly temperatures up to 24°C. Camps on the Gobi plains had less precipitation, higher temperatures with maximum monthly temperatures up to 30°C in summer. Snow coverage in the summer camps was shorter in the Gobi plains compared to the Altai highlands. In winter, minimum average temperatures were -31°C on the Gobi plains and -38°C in the Altai highlands. The total annual precipitation at camps in the Altai highlands was 1.4-1.5 times higher (217 mm in 2018; 203 mm in 2019) than at camps located on the Gobi plains (179 mm in 2018; 141 mm in 2019; Figure B1 in the appendix).

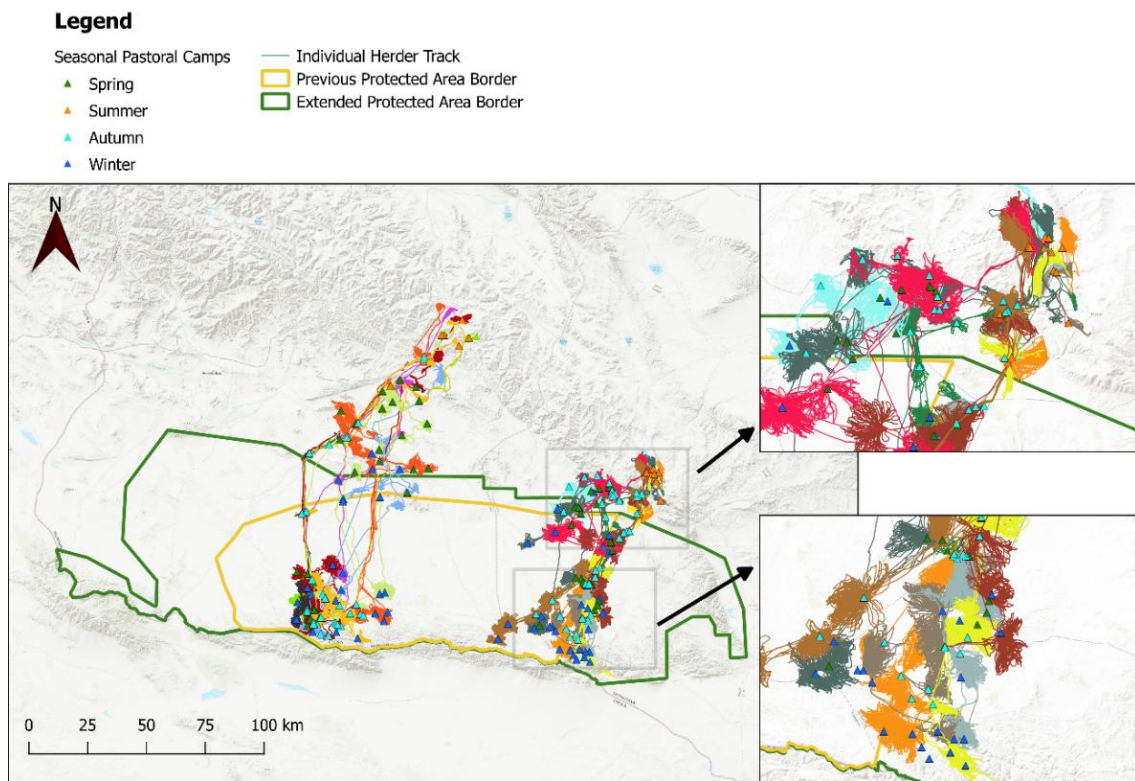


Figure 3.2: Small livestock herd tracks over a period of 20 months in the Great Gobi B Strictly Protected Area, Mongolia. Each colour represents a different herd in each region. Zoomed-in areas represent main summer and winter grazing areas.

3.3.2 Seasonal and daily mobility data

As described in Michler et al. (2022), we equipped one healthy, adult male goat in each of 19

herds with a lightweight GPS collar (CatLog Gen2, Perthold Engineering LLC, Dallas, TX) across two regions within the Great Gobi B SPA to document mobility patterns of mixed goat and sheep herds. We chose to collar goats for practical reasons as the GPS devices fitted the goats' body better than that of sheep. We deployed the collars over a 20 months period from the beginning of September 2018 to the end of April 2020. Due to costs and amount of time for field work we only sampled one summer season. However, despite the lack of replication for the summer season, the herds originated from a large geographic area covering a wide range of environmental variation.

We visually identified camp locations in the middle of dense clusters of GPS points and movement paths returning to a specific location in QGIS (2.18.18). Camps were then categorised by their season and year of use (SeasonalCamp), as described in more detail in Michler et al. (2022). To understand daily grazing mobility patterns, we identified the camp use duration (CampUse) and calculated the daily walking distance (WalkDist) as the sum of all consecutive distances between GPS fixes per day, and the daily maximum distance from camp (MaxDist) in km. We defined the daily pasture time (PastureTime) as time in hours per day spent by livestock on the pasture (defined as ≥ 100 m away from camp). Thus, PastureTime included not only grazing time, but also all other behaviours on the pasture such as drinking, walking, resting and ruminating. We determined movement activity of livestock herds with speed as proxy for livestock activity in km per hour between 7:00 and 22:00. Slower speed representing times of predominantly grazing and higher speed indicating walking activity. Total cumulative annual distance (TCAD) as proxy for annual total mobility was calculated by summing up the daily WalkDist over one year.

3.3.3 Biomass availability around seasonal herder camps

We used the EVI (enhanced vegetation index), as a proxy to estimate biomass availability within 5 km buffers around seasonal herder camps (maximum expected grazing distance from camp, Michler et al. 2022). We obtained the EVI from the image closest in time to the start of camp use via Google Earth Engine using the Terra Moderate Resolution Imaging Spectroradiometer layers (MODIS; MOD13Q1; Version 6), available at 16-d intervals (Didan, 2015; Paltsyn et al., 2019). We tested whether CampUse was dependent on biomass availability but excluded the winter season as snow cover does not allow for reliable EVI measurements.

3.3.4 Snow cover as trigger for winter camp moves

To identify whether the arrival of a permanent snow cover triggers herders to move to winter

camps on the Gobi plains, we obtained snow cover information for the Great Gobi B SPA from MODIS/Terra Snow Cover 8-Day L3 Global 500m SIN Grid, Version 61 (MOD10A2) from beginning of October until end of March in 2018 and 2020. We used the “maximum snow extent” data over an 8-day period with a 500-m resolution (Hall & Riggs, 2023). We defined snow arrival as first permanent snow cover when the maximum snow extent showed snow cover over a period of at least 16 days. Move dates of camps and the first permanent snow cover days were reported in Julian days.

3.3.5 Livestock Weight

To understand small livestock weight dynamics, we repeatedly weighed 8 adult goats and sheep (2 males and 2 females of each species) and 4 young of the year (1 male and 1 female each; totalling 228 adults and young in one year) in each herd with a hanging scale. The measuring took place in the morning before the animals left the camp for grazing to assure the animals had an empty stomach. As the offspring stay with their mother overnight, adult females did not have full udders. The animals were weighed in spring (April 2019/2020), when the weight is usually lowest after winter, and in autumn (October 2019), when weight is highest after the summer grazing period and before weight loss due to colder weather (Punsalma et al., 2013). Goats and sheep were marked with ear tags so that the same animals could be weighed in spring 2019, autumn 2019 and spring 2020.

3.3.6 Statistical analysis

To analyse the influence of EVI, season by year (SeasonalCamp), herd size (HerdSize), herd ratio (HerdRatio; goats/sheep), temperature (Temp) and days since herders started to use a camp (CampStart) on CampUse, PastureTime, WalkDist, and MaxDist, we used generalized linear mixed models in the package ‘glmmTMB’ (Brooks et al., 2017) of the statistical software R version R-4.0.3 (R Core Team, 2020). We derived the candidate models by trying out all possible combinations of all explanatory variables, using the Akaike Information Criterion (AIC; Cavanaugh & Neath, 2019). We, further, checked the assumptions for these models like homogeneity of variance, normal distribution and independence (no temporal autocorrelation) of errors. Response distributions of the models were selected based on whether model residuals were normally distributed. Before analyses numeric predictors were standardized as our data showed entirely different ranges of variation.

We considered the following full models with respective response distributions:

- CampUse in response to EVI, SeasonalCamp, HerdSize and HerdRatio (negative binomial distribution)
- PastureTime in response to EVI, SeasonalCamp, HerdSize, HerdRatio, Temp and CampStart (gaussian distribution)
- WalkDist in response to SeasonalCamp, HerdSize, HerdRatio, Temp and CampStart (gaussian distribution)
- MaxDist in response to EVI, SeasonalCamp, HerdSize, HerdRatio, Temp and CampStart (gaussian distribution)

HerdSize and HerdRatio were given in sheep forage units (SFU) with a conversion of 0.9 for goats as goats eat 10% less than sheep (Bedunah & Schmidt, 2000). For all models, we included HerderID as a varying intercept representing variation across the 19 herds. We identified the most parsimonious models based on the lowest AIC using the maximum likelihood method (Cavanaugh & Neath, 2019).

3.4 Results

3.4.1 Seasonal patterns of pastoral camp moves and camp use duration

EVI, SeasonalCamp and their interaction best explained CampUse by herders (Table 3.1, Figures 3.3 and B2). As expected, herders stayed longer at camps with higher biomass, with the effect being strongest in spring and summer. In contrast to our hypothesis, neither HerdSize nor HerdRatio led to more parsimonious models (Tables 3.1 and B2 in the appendix).

Contrary to our hypothesis that moves into the winter camps are linked to the arrival of a lasting snow cover, we did not find a consistent pattern between the timing herders moved to their first winter camp and the arrival of the first permanent snow cover (Figures S3 and S4). In 2018, 68% of herders moved up to 66 days before the first snow arrived while 32% of herders moved up to 40 days after the first snow has arrived. In 2019, 13% moved up to 16 days before the first snow arrived and 87% moved up to 27 days after snow arrival.

Table 3.1: Top five models that we used to estimate the camp use duration (CampUse) in the Great Gobi B Strictly Protected Area, Mongolia, based on GPS movement data collected in autumn 2018, spring 2019, summer 2019 and autumn 2019. The fixed explanatory variables in the model were: enhanced vegetation index (EVI), season by year (SeasonalCamp), herd size

(HerdSize) and herd ratio (HerdRatio; goats/sheep) in sheep forage units. Herder ID was included as a random effect in all models.

Model	AIC _c	Delta AIC _c	AIC _c Weight	Log-Likelihood
EVI + SeasonalCamp + EVI:SeasonalCamp*	32169	0.00	1	-16075
EVI + SeasonalCamp	32385	216	0	-16186
SeasonalCamp + HerdSize + SeasonalCamp : HerdSize	32622	453	0	-16301
SeasonalCamp + HerdRatio + SeasonalCamp : HerdRatio	32673	504	0	-16326
SeasonalCamp	32675	506	0	-16332

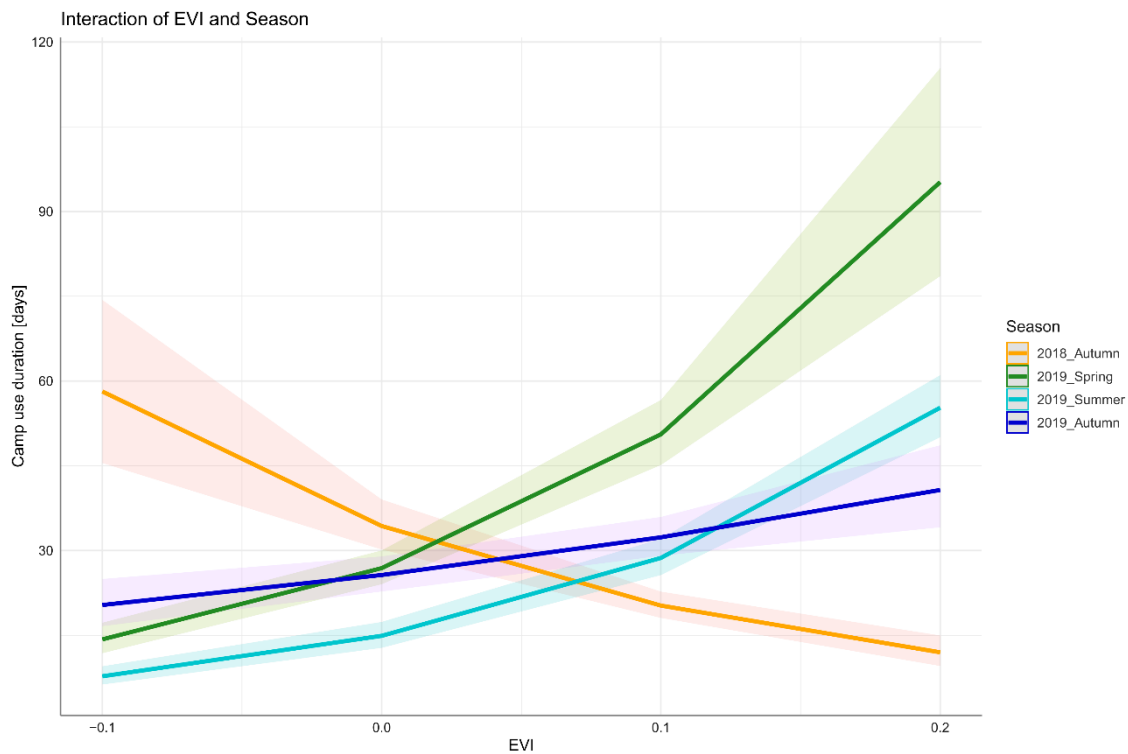


Figure 3.3: Predicted interaction of herder camp use duration (days) dependent on enhanced vegetation index (EVI) and season by year (SeasonalCamp). Herder camps were located in and around the Great Gobi B Strictly Protected Area, Mongolia.

3.4.2 Daily livestock mobility patterns

In line with our hypothesis, WalkDist and the MaxDist were determined by SeasonalCamp and CampStart. Small livestock walked more and further away from the camp with increasing camp use duration, particularly in spring but less strongly in autumn (Table 3.2, Figures 3.4 and 3.5). However, our results showed that neither EVI, temperature nor HerdSize and HerdRatio improved model parsimony (Tables 3.3, B1 and B2 in the appendix).

Table 3.2: Daily Livestock Movement Patterns: Time of the day for average grazing start (in hours) and end measured as first and last GPS point ≥ 100 m away from herder camp for different seasons. Daily pasture time (PastureTime) given in hours per day was calculated as time between grazing start and end. Daily walking distances (WalkDist) and daily maximum distance from camp (MaxDist) for 19 livestock herds monitored from September 2018 until April 2020 in the Great Gobi B Strictly Protected Area, Mongolia.

Season	Grazing Start Time	Grazing End Time	PastureTime [h/d]	WalkDist [km/d]	MaxDist [km]
Spring	10:22 $\pm$ 01:30	20:26 $\pm$ 01:14	10.1 $\pm$ 2.2	11.6 $\pm$ 3.7	4.3 $\pm$ 1.9
Summer	09:58 $\pm$ 01:22	21:17 $\pm$ 00:47	11.3 $\pm$ 1.7	10.2 $\pm$ 3.0	3.8 $\pm$ 1.7
Autumn	10:23 $\pm$ 01:16	19:26 $\pm$ 01:23	9.1 $\pm$ 2.1	9.0 $\pm$ 2.6	3.4 $\pm$ 1.3
Winter	11:21 $\pm$ 01:13	18:44 $\pm$ 01:22	7.4 $\pm$ 1.9	7.7 $\pm$ 2.5	3.1 $\pm$ 1.3

As expected, the PastureTime of small livestock was longest in summer, shortest in winter, and intermediate in spring and autumn (Table 3.2). PastureTime was mostly influenced by EVI and temperature (Tables 3.3 and B4 in the appendix, Figure 3.6). PastureTime increased with increasing biomass and rising temperatures. Neither CampStart, nor HerdSize and HerdRatio improved model fit.

Small livestock left camps by mid-morning and walked fast towards the most distant grazing point, which they reached around noon. Thereafter, livestock moved slower until the herders turned them back towards the camp in the late afternoon (Figure 3.4). Small livestock herds walked an average total cumulative annual distance (TCAD) of 3,520 km (range: 1,798 to 4,120 km).

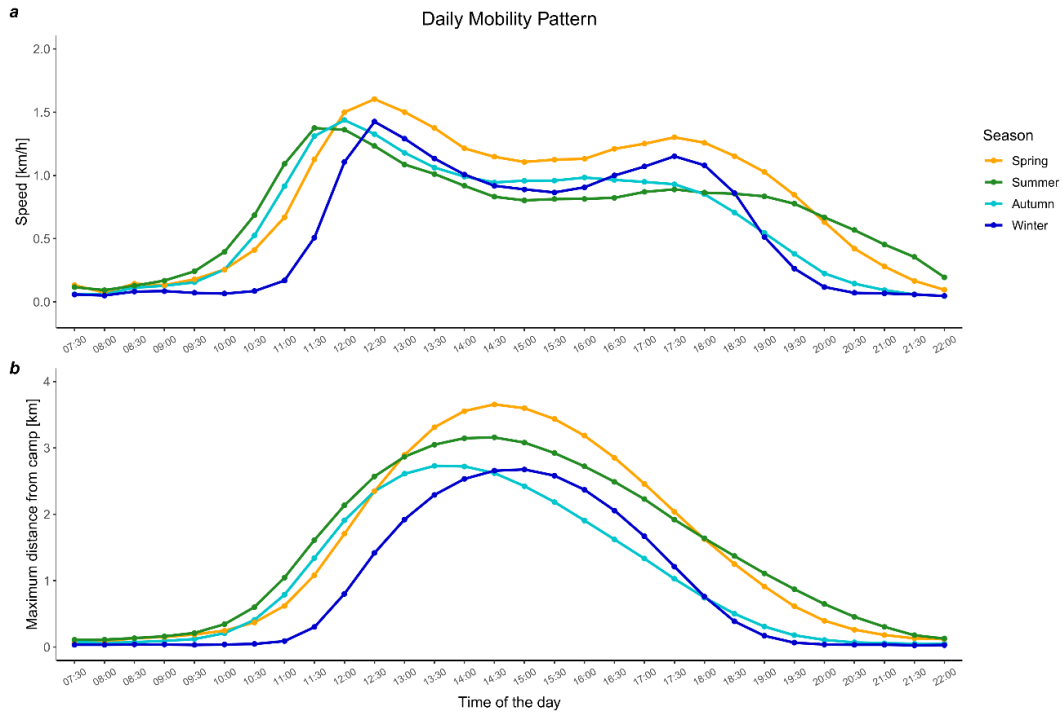


Figure 3.4: Daily mobility patterns (speed in km/h (a) and maximum distance from camp (b; MaxDist) in km) of 19 GPS tracked livestock herds in the Great Gobi B Strictly Protected Area, during the years 2018 to 2020 in Mongolia.

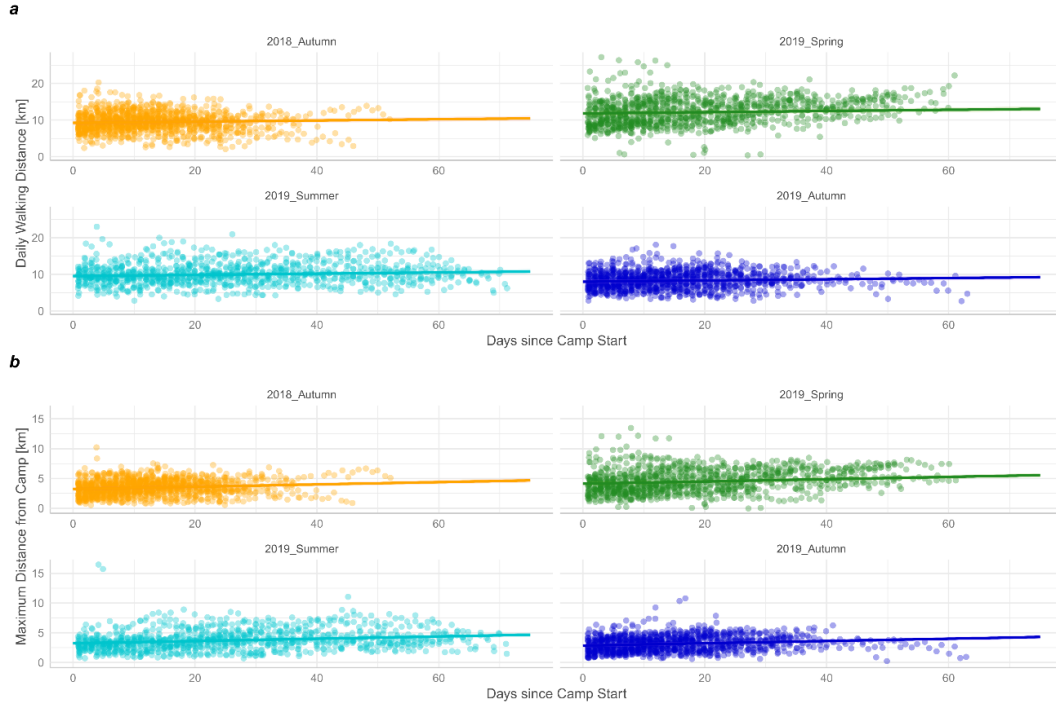


Figure 3.5: Daily walking distance (a) and maximum distance from camp (b) in km +/- prediction intervals (lines and shaded areas around) as a function of days since camp start in four different seasons.

Table 3.3: Top five models that we used to estimate daily pasture time (PastureTime), daily walking distances (WalkDist) and maximum distance from camp (MaxDist) by small livestock in the Great Gobi B Strictly Protected Area, Mongolia, based on GPS movement data collected in autumn 2018, spring 2019, summer 2019 and autumn 2019. The explanatory variables in the models were: enhanced vegetation index (EVI), seasonal camp location in respective years (SeasonalCamp), herd size (HerdSize) and herd ratio (HerdRatio; goats/sheep) in sheep forage units, temperature (Temp) and days since camp use start (CampStart). Herder ID was included as a random effect in all models.

Response Variable	Model	AIC _c	Delta AIC _c	AIC _c Weight	Log-Likelihood
PastureTime	EVI + Temp	17058	0	1	-8524
	Temp	17192	133	0	-8592
	Temp + CampStart	17192	133	0	-8592
	EVI + SeasonalCamp	17348	290	0	-8667
	EVI + SeasonalCamp + EVI : SeasonalCamp*	17348	290	0	-8667
WalkDist	SeasonalCamp + CampStart	20007	0	1	-9996
	EVI + SeasonalCamp	20028	21	0	-10007
	EVI + SeasonalCamp + EVI : SeasonalCamp	20028	21	0	-10007
	SeasonalCamp + HerdSize	20029	22	0	-10008
	EVI + SeasonalCamp + Temp + SeasonalCamp:Temp + HerdRatio	20029	22	0	-10008
MaxDist	SeasonalCamp + CampStart	14869	0	1	-7428
	SeasonalCamp + HerdSize	14985	116	0	-7485
	SeasonalCamp	14988	119	0	-7488
	HerdSize + Temp	14988	119	0	-7488
	EVI + SeasonalCamp	14989	120	0	-7487

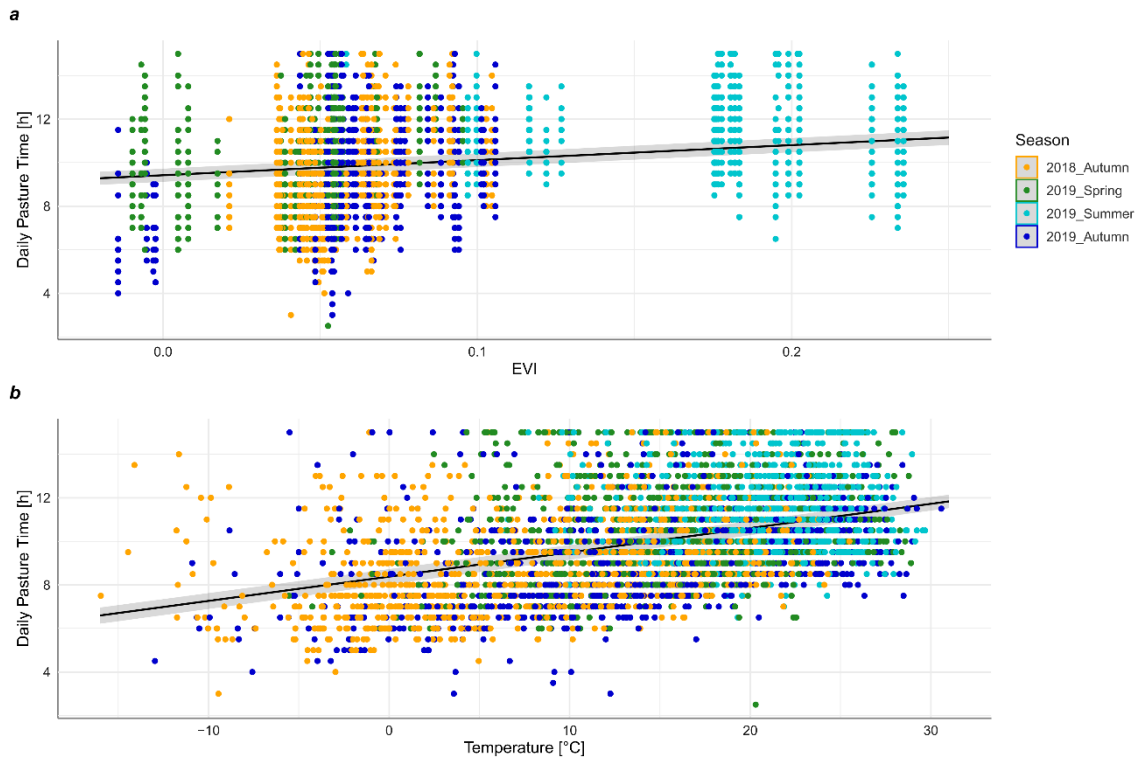


Figure 3.6: Daily pasture time (PastureTime; black lines) in hours of small livestock +/- prediction intervals (grey areas) in relation to biomass (EVI; a) and temperature (in °C; b) shown for season and year in the Great Gobi B Strictly Protected Area, Mongolia. Each colour represents different seasons.

3.4.3 Livestock body weights

As expected, body weights of adult sheep and goats were at the higher end of livestock weights in Mongolia (Table B5 in the appendix), averaging 50 kg and 63 kg for male and 32 kg and 41 kg for female goats in spring and fall respectively and 58 kg and 70 kg for male and 42.0 kg and 55 kg for female sheep in spring and fall respectively. Adult goats and sheep gained on average 18-23% (9-13 kg) of their body weight during summer and lost 11-20% (6-11 kg) during winter. Kids and lambs gained 68-70% (14-25 kg) during summer and lost none or hardly any weight during winter (Figure B5 in the appendix).

3.5 Discussion

3.5.1 Camp use duration – the importance of biomass

Our study supported our expectation that herder camp duration increases with increasing biomass availability; the effect was most evident in summer and spring. Surprisingly, the trend was opposite in autumn 2018, when additional rainfall in autumn led to a second green-up and herders moved in their winter camps although pasture around autumn camps was good. Previous work had already established that herders in the Dzungarian Gobi select areas of high biomass for their camp locations (Michler et al. 2022), and together it confirms that herder mobility is strongly linked to biomass availability both at the landscape scale (where to set up camp) and at the local scale (how long to use the pasture around camp). A similar pattern has been shown in other places in Mongolia (Liao et al., 2014).

Contrary to our expectation, the arrival of the first permanent snow cover was a poor predictor for the timing of herders moves to the first winter camp. The arrival dates were also spread over a longer time than we had expected and varied between the years. This might be explained by the importance of biomass for camp use duration, which was also observed in autumn although to a lesser extent than in summer and spring. Informal conversations with local herders further revealed that they postpone moving to winter camps as long as possible if sufficient pasture is available elsewhere and weather conditions allow for it. Our findings contrast the findings of Behnke et al. (2011), who reports that the arrival of snow and colder temperatures trigger moves into the winter camps.

In the Dzungarian Gobi, good winter camp locations are limited, as they need to provide sufficient pasture, shelter, and reliable access to snow for water during a period when mobility is lowest (Michler et al. 2022). When moving too late, herders risk getting trapped by high snow in a poorly sheltered camp, which can result in high livestock mortality (Kaczensky et al., 2011). When moving too early, they risk depleting their winter pasture(s), especially in years when pasture productivity is low, or the winter is unusually long. The large variation in the arrival dates seems to indicate that risk assessment happens at the herder level (i.e., based on individual choice), rather than at the level of the community or around a specific date. Since the political change to a democracy in the early 1990s, individual decisions by herders are common in Mongolia. However, to improve rangeland health, communal pasture management decisions are fostered by many governmental and non-governmental organisations (Kasymov et al., 2023; Upton, 2008).

3.5.2 Livestock pasture mobility

Sheep and goat in the Dzungarian Gobi have a diurnal grazing pattern characterized by high walking activity in the morning, and grazing activity around noon and in the afternoon, until livestock is slowly walking back to the camp in the evening, typical for tended herds of small livestock in arid systems (Birrell, 1991; Fierro & Bryant, 1990; F. J. C. Joly et al., 2013; Jordan et al., 2016b; Kawamura et al., 2005; Lin et al., 2011). As expected, daily walking distance and maximum distance increased with camp use duration and were influenced by season.

Biomass availability did not influence walking distance, but the increasing removal of biomass through prolonged grazing was most likely the driver behind the positive relationship between camp use duration and the daily walking and maximum walking distances. The increase in walking distance and maximum distance, either caused by the herd because there is less to feed on, or by the herder because the pasture closest to camp no longer provides what the herd needs, may be the cue which triggers the move to a new camp. In Western Mongolia herders report that movement to their summer camps depends on (1) environmental factors like rising temperatures, snow melt, and lower biomass at spring camps, (2) behavioural observation of their lead animals, and (3) social aspects like moving when the neighbour moves (Altmann et al., 2018).

As we expected, the time small livestock spent on the pasture increased with increasing biomass and temperature. In winter, spring, and autumn, temperatures often fall below the critical lower temperature for sheep and goats (Fonseca et al., 2016; Holmes & Moore, 1981; van Wettere et al., 2021), so that higher temperatures have a positive influence on pasture time. This positive effect of moderately high temperature on pasture time suggests that herders avoid heat stress for their animals by migrating to higher altitudes. Cool temperatures and long grazing times on high quality pasture in summer allow small livestock to regain bodyweight and fatten up for the next winter, reaching body weights at the higher end of the scale typical for Mongolia. Although, season had no obvious influence on pasture time in our study, biomass availability and temperature were strongly linked to season.

Grazing mobility, presented in our data by daily walking distances and maximum distance from camp, was slightly lower than for sheep and goat herds in other areas in Mongolia and Inner Mongolia (Kawamura et al., 2005; Tsevegemed et al., 2019). This suggests that either the pasture in the Dzungarian Gobi is more productive, or grazing pressure is lower as only limited access to herders in the protected area is given (Sansarbayar, 2019). In a previous study, we showed how long travel distances and frequent camp moves impede pasture depletion (Michler et al., 2022). Total cumulative annual movement distance (TCAD) of small livestock herds

averages 3,520 km which is almost identical to the average 3,464 km of the similar-sized Mongolian gazelle (*Procapra gutturosa*, famous for its large-scale nomadic movements; Joly et al. 2019; Dejid et al. 2022). The high overall mobility of tended small livestock herds in combination with the lack of evidence for obvious pasture degradation around herder camps in the Dzungarian Gobi (Michler et al. 2022) suggests that herders move camps before overgrazing the pasture around their camps. Within the Dzungarian Gobi environmental change through pasture degradation is not evident yet (Michler et al., 2022), however, socio-economic changes along with increasing livestock numbers are raising concerns over pasture health potentially leading to alterations of the environment (Michler et al., 2024).

Contrary to our expectation, herd size and herd ratio did not seem to affect herd mobility patterns, which was most likely due to our small sample size of 19 herds (Table B6 in the appendix). However, if herders do not adapt camp use duration and grazing mobility as a function of herd size, grazing pressure intensifies. Considering the ongoing increase in livestock numbers in Mongolia (Mongolian Statistical Information Service, 2023) the impact of larger herd sizes on mobility pattern and rangeland health need to be closely monitored.

3.5.3 Advantage of altitudinal migration

In Mongolia, mountain ranges are used as traditional summer pasture where available (Retzer et al., 2006), as it allows for optimal resource use due to different climate conditions and pasture dynamics along the elevational gradients (Hsiung et al., 2018). Differences in the temperature and precipitation regime around herder camps on the Gobi plains and the Altai highlands clearly show that by migrating to higher altitudes, herders are able to escape the worst of the summer heat. Due to the higher precipitation, they also gain access to pastures with higher biomass availability (Michler et al., 2022; Retzer et al., 2006).

Both, very high and very low temperatures entail high energy expenditure (Arnold et al., 2004; Trondrud et al., 2021). To survive the very cold winter months in Mongolia, livestock therefore has to gain sufficient fat reserves during the short vegetation period. Therefore, body weight is an important indicator of the animal's fitness and in livestock is linked to economic value. Adult Mongolian native sheep and goats in the Dzungarian Gobi were slightly heavier than the Mongolian average and at the higher end of some other breeds common in the region (Table B5 in the appendix; Jamsran et al., 2018). They lost less body weight (11-20%) during winter than sheep and goats in other parts of Mongolia (21-30%; Jargalsaihan et al. 2021; Tumurjav 2003). In areas with extreme temperature differences, thermal stress is a concern for livestock production. Heat-stressed livestock tend to seek shelter and reduce activity to minimise costs for

thermoregulation. This reduces grazing time which in turn results in lower body weights, poorer reproduction, and higher mortality (Goma & Phillips, 2022; van Wettere et al., 2021).

The altitudinal migration of herders between the Gobi plains and the Altai highlands reduces exposure of livestock to very high summer temperatures on the Gobi plains and very low winter temperatures in the Altai highlands. Furthermore, altitudinal migration allows livestock a longer window of access to highly nutritious young vegetation by following vegetation green-up referred to as surfing the “green-wave” (Bischof et al., 2012; Fryxell & Avgar, 2012). This illustrates how the altitudinal migration benefits small livestock fitness and shows that this grazing regime is benefitting livestock production.

3.6 Conclusion

We found that camp use duration and the decision to move camps are primarily driven by biomass availability and season. By embarking on altitudinal migration, herders avoid the extreme summer heat of the Gobi plains and the extreme winter cold of the Altai highlands. This allows small livestock to obtain above average body weights compared to other regions in Mongolia. These results in combination with the previously documented frequent camp moves and the lack of evidence for obvious pasture degradation in the Dzungarian Gobi suggest that herders in the Dzungarian Gobi still operate well below the irreversible threshold of ecological change. However, the continuously rising livestock numbers are of concern for rangeland health and wildlife conservation, especially because winter and many of the spring and autumn pastures of local herder families fall within the Great Gobi B Strictly Protected Area. Although local herders and wild herbivores have coexisted on shared pastures for millennia, the combination of ever-increasing livestock numbers and climate change can be expected to reduce resilience of both local herders and wildlife to environmental change. To counteract this threat, management should aim to maintain the high level of mobility of domestic and wild herbivores and regulate stocking densities.

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Chapter 4 What will the future bring? – Socio-economic challenges to herder households in the Great Gobi B strictly protected area in Mongolia



Figure 4.1: Raw cashmere combed from goats of a herder family in the Great Gobi B Strictly Protected Area in Mongolia (Photo by Lena Michler, 2022)

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What will the future bring? – Socio-economic challenges to herder households in the Great Gobi B strictly protected area in Mongolia

Lena M. Michler^{1,2}, Petra Kaczensky^{3,4}, Daginnas Batsukh^{5,6}, Anna C. Treydte^{1,7}

¹ Department of Ecology of Tropical Agricultural Systems (490f), Institute of Agricultural Sciences in the Tropics (Hans-Ruthenberg-Institute), University of Hohenheim, Stuttgart, Germany

² International Takhi Group, 8135 Sihlwald, Switzerland

³ Department of Forestry and Wildlife, Faculty of Applied Ecology, Agricultural Sciences and Biotechnology, Inland Norway University of Applied Sciences, Norway

⁴ Research Institute of Wildlife Ecology, University of Veterinary Medicine, Vienna, Austria

⁵ Darkhan campus, Mongolian University of Life Sciences, Darkhan, Mongolia

⁶ Climate International Cooperation Department, Incheon National University, Republic of Korea

⁷ Department of Physical Geography, Stockholm University, Stockholm, Sweden

4.1 Abstract

Nomadic pastoralism is still practiced by around one-third of the Mongolian population. Recent socio-economic constraints have challenged pastoral livelihoods and rising livestock numbers threaten overall rangeland health and biodiversity conservation. In the Mongolian Gobi, herder households fully depend on livestock production but little is known about their livelihood trends and potential compatibility with protected area goals. We combined interview data in the Great Gobi B strictly protected area (SPA) with secondary data on regional and national herder households to determine the importance of social networks, willingness to continue a herding lifestyle, and degree of involvement in protected area (PA) management. Our descriptive data confirm that herding is no longer centred on a subsistence lifestyle but rather around cashmere production. Contrary to sustainability goals, especially in protected areas, herder households continue to increase livestock numbers in response to high expenditures in the economic reality of a market economy. We conclude that herders in the Great Gobi B SPA are reaching neither socio-economically nor ecologically sustainable livestock numbers which challenge herders' livelihoods and PA management alike. We recommend enhancing communication between the PA management and the herding community and increasing participatory conservation activities. National strategies are needed to resolve the current dilemma of increasing livestock numbers to meet livelihood demands and the growing threat to rangeland health.

Keywords: *Pastoralism, Livestock numbers, Protected area management, Dzungarian Gobi, Mongolia*

4.2 Introduction

Extensive livestock husbandry on rangelands is important for the livelihoods and food security of 20 million herder households worldwide (FAO, 2001; Lund, 2007). Nomadic pastoralism has been practiced over millennia, especially in arid regions unsuitable for other agricultural production (Godde et al., 2020). However, in many rangeland systems globally changes in socio-economic conditions result in shifts from nomadic to sedentary forms of livestock grazing and increased rural-urban migration (Manzano et al., 2021). In addition, climatic extremes are challenging this traditional lifestyle, particularly in the most arid rangelands (Fernández-Giménez et al., 2017). While rangelands are widely studied (Addison et al., 2012; Godde et al., 2020), herders livelihood trends are poorly understood resulting in inadequate policy decisions (Johnsen et al., 2021).

In Mongolia, one-third of the population practice pastoral livelihoods (Mongolian Statistical Information Service, 2023) but the livestock sector has undergone multiple changes in the last century. For over 60 years, all herder households were part of livestock collectives and herded state-owned animals for a salary (Fernández-Giménez, 1999). With the end of the Soviet era, many people returned to household herding (Dyer et al., 2022; Fernández-Giménez et al., 2017; Meurs et al., 2017). Privatization and the development of an export market for cashmere wool has led to a shift from a subsistence to a market economy (Meurs et al., 2017), where herders have increased their livestock numbers, especially of cashmere goats (Berger et al., 2013; Wei & Zhen, 2020). Fluctuating cashmere prices and the unpredictable and harsh climate are challenging for the economy of herder households (Sternberg, 2008) and have increased livelihood vulnerability (Marin, 2019), while the rising livestock numbers put increasing pressure on the fragile rangelands threatening pasture health and the long-term viability of the pastoral economy (Addison & Brown, 2014).

Herder households in remote, rural areas no longer have access to free public services and only limited access to healthcare (WHO, 2021) and education (Ahearn & Bumochir, 2016; Steiner-Khamisi & Gerelmaa, 2008); around 30% of the rural Mongolian population live below the poverty line (World Bank, 2019). Along with the shift from subsistence to a market economy, labour previously shared within the extended family is increasingly outsourced to contracted herders (Murphy, 2015). While, especially in remote areas, the importance of kinship relations and social networks for herder household livelihoods remains high (Conte, 2022; Fernández-Giménez et al., 2017; Ichinkhorloo, 2018) increased rural-urban migration especially of younger Mongolians to seek labour or higher education (Park et al., 2017) has resulted in

declining household numbers. This trend could potentially reduce overall grazing pressure but may also alter the livestock grazing sector from a household enterprise to a large-scale ranching style system (Fernández-Giménez et al., 2017). Socio-economic constraints already force many herder households to abandon the nomadic household-centred lifestyle during winter months, when women and children live in district or provincial centres where the schools are located, and men stay with the herds (Ahearn, 2018). These social changes result in increased livelihood costs, which in turn lead to rising livestock numbers, absentee herders, and increasing social inequality (Fernández-Giménez et al., 2017).

Livestock numbers in grazed and industrial systems are on the rise globally (FAO, 2022). Grazing systems have expanded and are used more intensively (Godde et al., 2018), leading to more land-use conflicts in or close to protected areas (DeFries et al., 2007). In Mongolia, where livestock grazing is practiced within most protected areas, the cash benefits of cashmere and the privatization of livestock production triggered a sharp increase of livestock number in the last decades (Rao et al., 2015; Wei & Zhen, 2020), posing challenges for biodiversity conservation, wildlife management (Kaczensky et al., 2020; Salvatori et al., 2021) and rangeland health (Fernández-Giménez et al., 2018). Currently high livestock numbers are not only threatening pasture productivity and biodiversity, but also, the nomadic herding culture depending on these very rangelands (Sainnemekh et al., 2022) and make herding communities more vulnerable to climate extremes (Sternberg, 2008). Protected areas are increasingly perceived and used as emergency pastures during droughts and harsh winter conditions (Bedunah & Schmidt, 2004; Hess et al., 2010), putting additional pressures on sensitive ecosystems during times when resources are already scarce and creating social conflicts (Bedunah & Angerer, 2012; Bedunah & Schmidt, 2004). In addition, rising livestock numbers could potentially increase competition with wild ungulates for decreasing resources (Niamir-Fuller et al., 2012), reduce wildlife numbers (Prins, 2000), and increase the risk of disease transmission between wild and domestic ungulates (Dayaram et al., 2021). Involvement of local communities in biodiversity monitoring and protected area decision making can mitigate conflict by focussing on common goals and finding a common knowledge base (Xu et al., 2006). Ultimately, sustainable use and biodiversity conservation require that livestock numbers and distribution are controlled.

Within the context of the regional and country-wide socio-economic trends over the last 20 years, we used semi-structured interviews to address four aspects of contemporary nomadic pastoralism in the Great Gobi B SPA:

- 1) the number and species of domestic animals that local herder households in the Great Gobi

B SPA need for maintaining their livelihoods.

- 2) the current economic situation of local herder households in the context of regional and country-wide trends;
- 3) the importance of pastoralists' social networks and labour division under the ongoing socio-economic changes;
- 4) the perception of herders on using pasture resources in Great Gobi B SPA and their interaction with the Great Gobi B SPA's management.

We conclude with recommendations for pastoral livelihoods in the Great Gobi B SPA under current and potentially reduced livestock numbers to sustainably manage the pasture resources for wildlife and pastoral livelihoods in the future.

4.3 Material and Methods

4.3.1 Study site

The Great Gobi B SPA was established in 1975 and registered in 1991 as UNESCO Man and Biosphere reserve (UNESCO, 2020). Since expansion in 2019, the protected area spans over 18'000 km² across two provinces (Khovd and Govi-Altai) and five districts (Soum) (Figure 4.2; Sansarbayar, 2019). Around 280 herder households and their livestock, namely (in decreasing order of importance) goats (*Capra aegagrus hircus*) and sheep (*Ovis aries*), cattle (*Bos taurus turano mongolicus*), horses (*Equus ferus caballus*), camels (*Camelus bactrianus*), and yaks (*Bos grunniens*) have seasonal access to the limited use zone of the protected area (Michler et al., 2022), while the core and protected zones are exclusively reserved for wildlife. Rare and endangered wildlife species of Great Gobi B SPA include the Przewalski horse (*Equus ferus przewalskii*), Asiatic wild ass (*Equus hemionus*), goitered gazelle (*Gazella subgutturosa*), Argali sheep (*Ovis ammon*), Siberian ibex (*Capra sibirica*), and snow leopard (*Panthera uncia*; Clark et al., 2006; Kaczensky et al., 2007). This semi-desert and desert steppe has a harsh, continental climate characterized by extreme temperature differences of up to 80°C between summer and winter, and highly variable precipitation (von Wehrden et al., 2009).

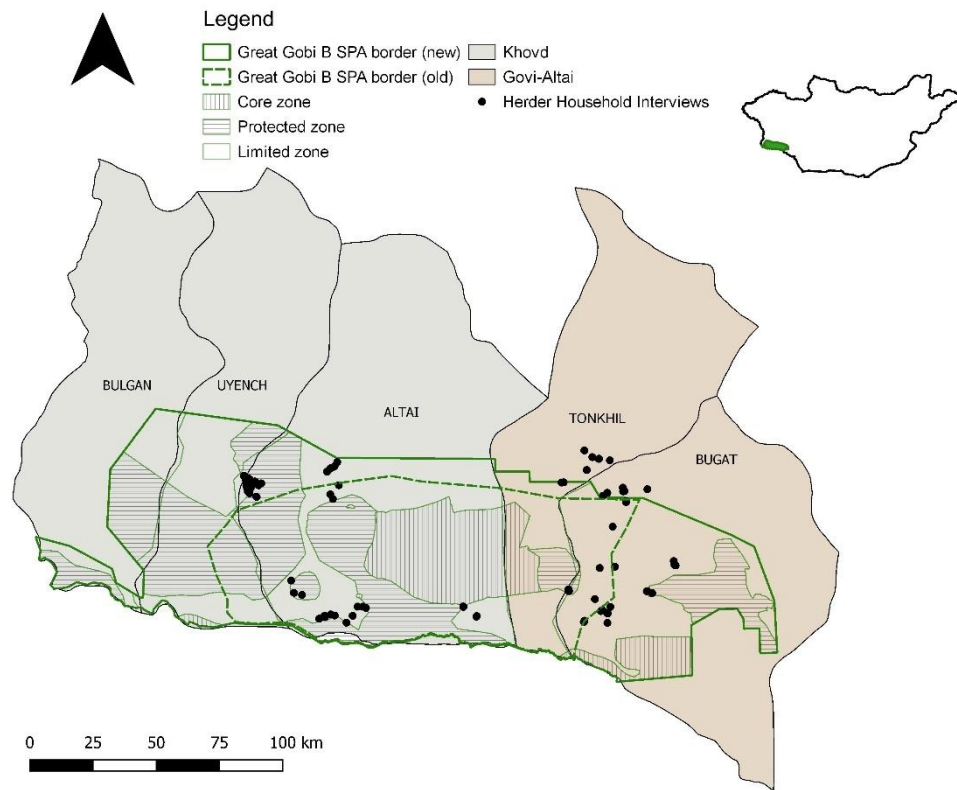


Figure 4.2: Location of the Great Gobi B strictly protected area covering five districts in two provinces (Khovd = Bulgan, Uyench, and Altai; Govi-Altai = Tonkhil and Bugat) in Mongolia. The different protection zones of the Great Gobi B strictly protected area are shown with vertical hatching = core zone, horizontal hatching = protected zone, and without hatching = limited use zone. The locations of interviewed herder households are shown with points

During the time of our study, herder households were allowed to use the pastures in the limited use zone in winter, based on contracts with the protected area (Altansukh Nanjid, director of the Great Gobi B SPA, pers. comm. 2022; Law of Mongolia on Specially Protected Areas, 1994). To date, there is little evidence for pasture degradation likely due to the combined effect of the non-equilibrium nature of the pastures (von Wehrden et al., 2012) and the high mobility of the herders (Michler et al., 2022). However, with rising livestock numbers in combination with fodder provision, there is concern over pasture degradation, as high grazing intensity is known to lower plant species diversity, biomass and vegetation cover (Menezes et al., 2020; Munkhzul et al., 2021), alter soil parameters (Abdalla et al., 2018; Zhang et al., 2022), and lead to soil erosion (Dong et al., 2022). In addition, decreasing livestock herd mobility and changes in pastoral management practices further threaten rangeland health (Fernández-Giménez et al., 2018; Manzano et al., 2020, 2022).

4.3.2 Herder household interviews

We conducted semi-structured interviews (Kallio et al., 2016) with 125 herder households in the Great Gobi B SPA in autumn 2017 and 2018 (Table C1 and C2 in the appendix), which represented 96% of all herder households who used seasonal camp locations within the protected area at that time¹. We identified the interviewed herder households with the help of the Great Gobi B SPA rangers. We structured interview questions to address household information, livestock situation, and economic conditions. Before the interviews, we informed the participants about the aim of the study and obtained signed informed consent of the interviewee (Nijhawan et al., 2013). Interviews were conducted in Mongolian and translated into English. In most cases the household heads (married couples) were interviewed together. The average age of household heads was 46 (± 12) years for men (N=120) and 44 (± 12) for women (N=121). Households had on average 4 (± 2) children with an average age of 17 (± 10) years.

4.3.3 Focus group discussions

During three focus group discussions in November 2019 (Michler et al. 2022), we asked 36 participants (11 women and 25 men) to complete a survey about information exchange between the pastoral community and the PA management. Questions covered the degree of collaboration, conflicts among the stakeholders, challenges regarding co-operation for conservation, and participation in certain management decisions concerning sustainable pasture use in the protected area following Batsukh & Benediktsson (2019) (Figure C1, C2 and C3 in the appendix).

To learn more about future prospects of herding, in autumn 2019 we conducted one focus group discussion with three female and six male herders, average age 27 (± 5) years to address the challenges and visions of young herder households. The discussion was led by a moderator and an assistant (Krueger, 2014). During the discussion, we took notes simultaneously in Mongolian and English. We asked each participant to answer six general questions as background information (Table C3 in the appendix) and divided the participants into three groups (two men and one woman each). Then we asked the groups to discuss seven questions jointly from the perspectives of: (1) livestock husbandry, (2) pasture use, and (3) social and household aspects (Table C4 and C5² in the appendix).

¹ The study started before the extension of GGB SPA in 2019 (Figure 4.2)

² The focus group was very small and was convened opportunistically and hence we present this data only in the Online Resource and discussion.

4.3.4 PA ranger interviews

We conducted two group expert interviews with six rangers of the protected area in autumn 2019. We interviewed three rangers each of the eastern and western parts of the Great Gobi B SPA together. The qualitative interviews were recorded and transcribed in Mongolian and translated to English while notes were taken in Mongolian and English simultaneously. During that time only seven rangers were employed in the Great Gobi B SPA, but the sample size is still very low and, therefore, we present the data in only the discussion.

4.3.5 Secondary data on national herder household and livestock data

We used data from the Mongolian National Statistics Office (2023) to obtain national and regional trends in livestock numbers, livestock species distribution, monetary expenditures and income, as well as overall population, education, and herder household numbers (Figure 4.3). To illustrate trends in household living costs, we used the Consumer Price Index of Mongolia (Mongolian Statistical Information Service, 2023), a measurement to show changes in consumer prices over time based on a representative basket of goods and services (Fernando, 2024). We compared the Consumer Price Index with data on national and regional prices for “brown greasy cashmere” (Figure 4.3).

For national trends, we used averages for all of Mongolia and for regional trends, we used data from the provinces of Khovd and Govi-Altai, or from the five districts that intersect Great Gobi B SPA and the buffer zone (Figure 4.2). We defined the information of our own interviews (N=125) in the Great Gobi B SPA in 2018 as local data.

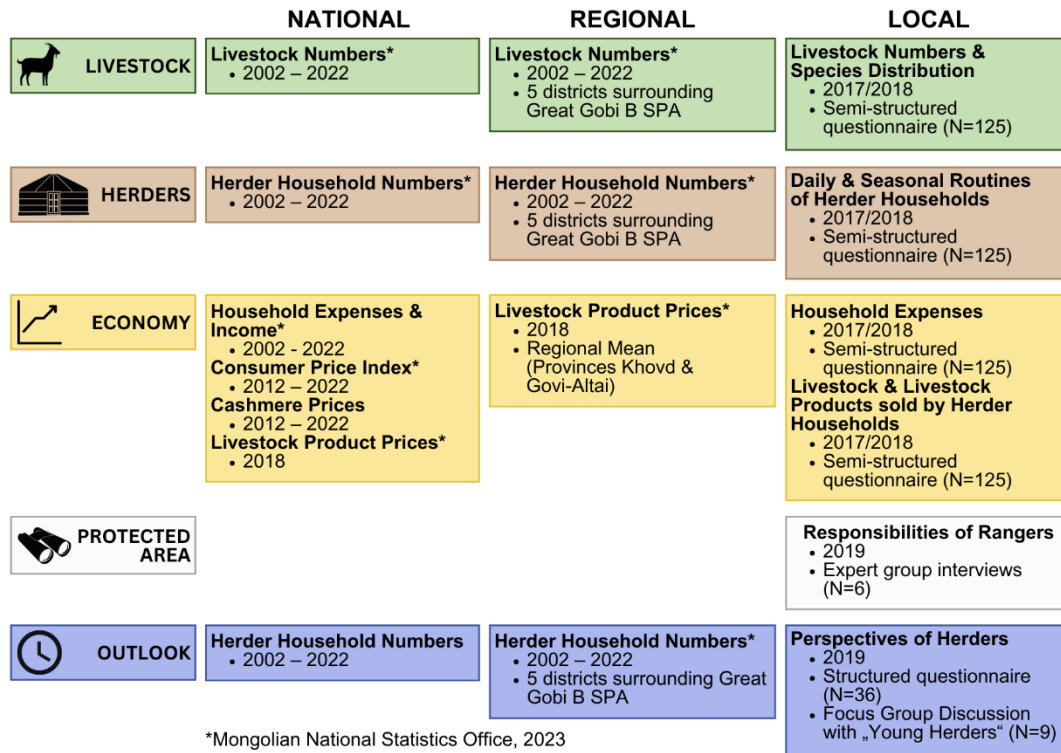


Figure 4.3: Schematic graph of data collection from the years 2002 to 2022 in Mongolia (national), in the provinces and districts surrounding Great Gobi B strictly protected area (regional), and in 2017/2018 inside the Great Gobi B strictly protected area (local), Mongolia. The figure illustrates how we investigated livestock and herder household trends, herder household economy and future outlooks of the herder lifestyle using various data sources

4.3.6 Data analysis

Data from structured and semi-structured questionnaires were analysed descriptively reporting percentages, means, and standard deviations. Answers to the open-ended question in the focus group discussions were reported by main categories that emerged according to Okoko et al. (2023).

4.4 Results

4.4.1 Herd sizes needed for maintaining pastoral livelihoods

A total of 71,120,433 livestock (goats, sheep, horses, cattle, yaks, and camels) were reported for 248,296 herder households (286 livestock per herder household) in Mongolia for the year 2022 (Figure C4 in the appendix), mostly sheep and goats, both of which have risen sharply over the last 20 years (Figure 4.4). The drop in national and regional livestock numbers in 2010 was due to severe winter conditions in 2009/10 resulting in mass mortality of over 20% of the national livestock population (Nandintsetseg et al., 2018; Rao et al., 2015).

Regionally, a total of 1,041,537 livestock were reported for 4,569 herder households (227 livestock per herder household). The percentage of goats was 12% higher than the national average. Regional livestock numbers followed a similar trend and were more severely affected by the 2009/2010 winter conditions.

The self-reported livestock numbers of the 125 interviewed households in 2017/2018 totalled 81,601 (mean: 653 ± 457 per household), with goats and sheep dominating in about the same proportion as in the regional data (Fig. 3). Most herders reported that they had increased their livestock herds over the previous three years, that they would like to further increase their herds, particularly their goats and sheep, and 65% wanted to increase their livestock products as well, especially cashmere production (23%). Herders told us that they would need for on average 774 (± 452) sheep and goats to guarantee a good living, 16.4% more than they owned at the time of the interview. In addition, five herders who specialized in raising cattle reported that they needed on average 180 (± 45), equalling 1080 (± 268) sheep forage units (SFU)³ for a good living.

³ SFU = Sheep forage units are used in Mongolia to compare livestock species to the consumption of one sheep. The sheep unit equivalent of cattle is six (Bedunah & Schmidt, 2000).

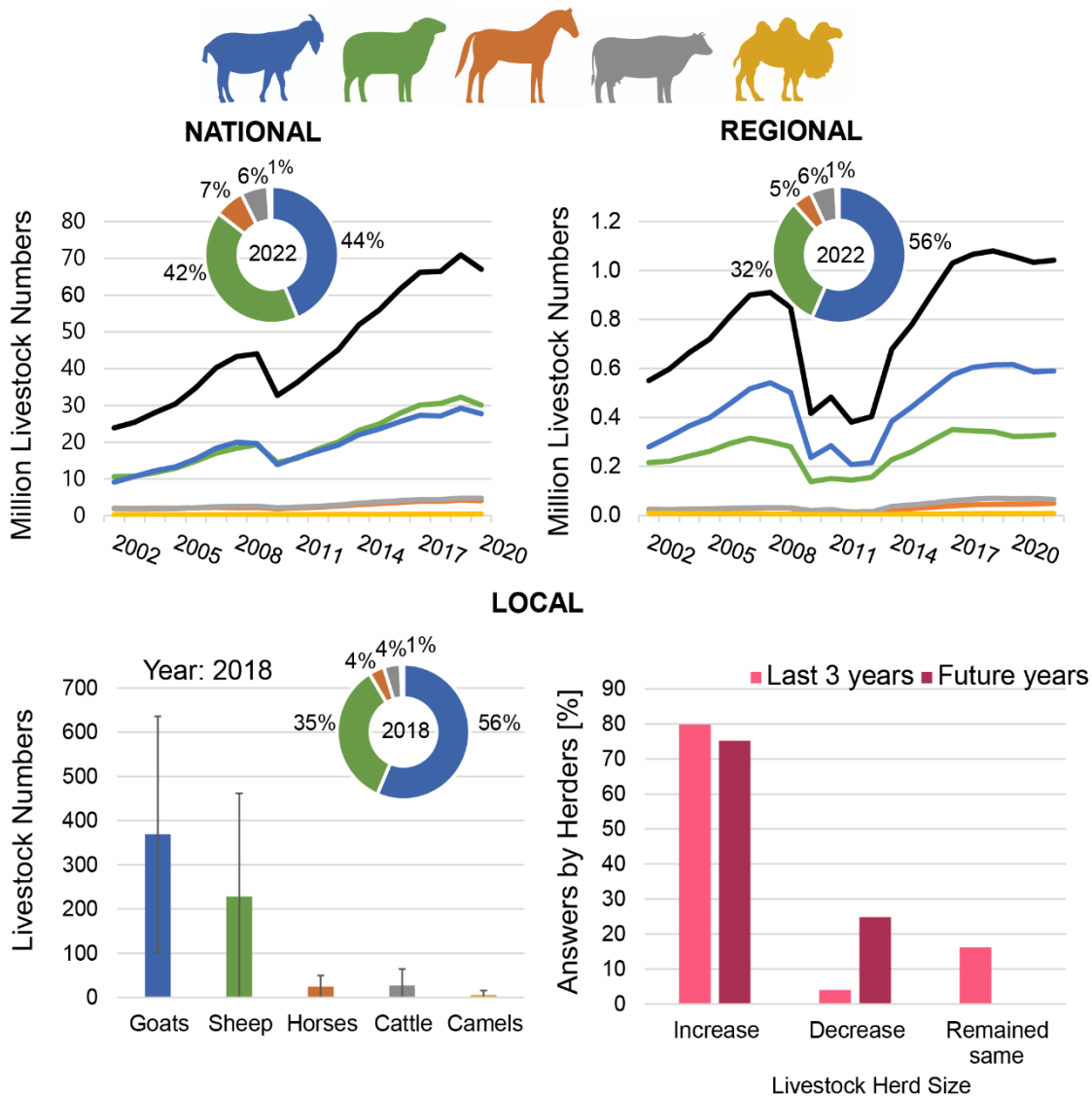


Figure 4.4: Livestock numbers and livestock species distribution in Mongolia (national), within the five districts surrounding Great Gobi B SPA (regional) and mean livestock numbers per herder household within the Great Gobi B SPA area, Mongolia (local). National and regional data are shown within the last 20 years (Mongolian Statistical Information, 2023) and local data are based on 125 herder household interviews conducted in 2017 and 2018. Colours represent different livestock species and the black line shows the total livestock population trends. The pie charts show the respective livestock species distribution. The right bar graph shows trends of herd size numbers over the last three years and preferred livestock trend for future years based on interviews with herder households (N=125)

4.4.2 Local herder household economy

Locally, 54% of interviewed households had no income source other than livestock and 44% generated $\geq 75\%$ of their income from livestock, with the remainder mainly in the form of government funds for child support (45%, $n = 55$) and/or pensions (49%, $n = 55$). Only three herder families reported a salaried job in addition to herding livestock.

Cashmere was the most important livestock product, harvested annually over the entire lifespan of the animals (Figure 4.6, Table 4.1). We found that local cashmere prices in the Great Gobi B SPA were 3% higher in 2018 than the annual national average, but slightly lower than regional cashmere prices (Table 4.1). Herders in the Great Gobi B SPA sold their cashmere mainly to middlemen at the regional market price of the Khovd and Govi-Altai provinces.

Table 4.1: Local livestock product prices reported by 125 herder household interviews in the Great Gobi B SPA, Mongolia, in 2017/2018, mean national average prices within Mongolia, and the regional prices in Khovd and Govi-Altai provinces in 2018. Data sources: interview data (local prices) and Mongolian Statistical Information Service, 2023.

Livestock Products	Livestock species	Mean National Prices [US\$]	Regional Mean Prices [US\$]	Local Prices [US\$]	N (Number of herders reporting local prices)
Cashmere / Wool [price / kg]	Goat	22.0 ± 6.3	23.4 ± 5.6	22.7 ± 4.9	117
	Sheep	0.9 ± 0.1	0.9 ± 0.1	0.6 ± 0.5	107
	Camel	3.1 ± 0.8	3.1 ± 0.9	1.6 ± 0.9	40
Hide [price / animal hide]	Goat	4.7 ± 3.9	4.1 ± 4.5	5.4 ± 1.7	114
	Sheep	0.6 ± 0.2	0.7 ± 0.2	0.8 ± 0.7	88
	Horse	3.3 ± 0.6	3.0 ± 0.9	5.3 ± 1.9	19
	Cattle	4.1 ± 2.1	3.6 ± 1.2	5.8 ± 3.8	39
	Camel	-	-	5.6 ± 6.2	4
Live animal prices [price / animal]	Goat	17.6 ± 6.4	16.0 ± 6.3	17.0 ± 3.1	103
	Sheep	25.4 ± 8.4	24.0 ± 7.8	22.6 ± 5.2	95
	Horse	155.8 ± 36.7	150.9 ± 34.1	156.1 ± 29.4	50
	Cattle	181.6 ± 48.9	165.4 ± 46.0	201.2 ± 50.9	48
	Camel	192.7 ± 51.4	185.7 ± 69.9	237.5 ± 44.2	15

Between 2012 and 2022, national and regional cashmere prices fluctuated widely between 12 and 28 US\$/kg, but with an overall upward trend (Figure 4.5). The drop of the cashmere price in 2020 was due to the global Covid-19 pandemic (Hafey, 2020). Over the last 10 years, the consumer price index has steadily increased at only a slightly lower rate than cashmere prices. On average, herders in the Great Gobi B harvest 300g of raw cashmere per goat and for an average of 2,513 US\$⁴ per year in 2018 and 2019 (assuming average goat herd size of 369 and the local cashmere price of 22.7 US\$).

⁴ Exchange rate on 15.06.2023: 1 \$US = 3,438 MNT (www.mongolbank.mn)

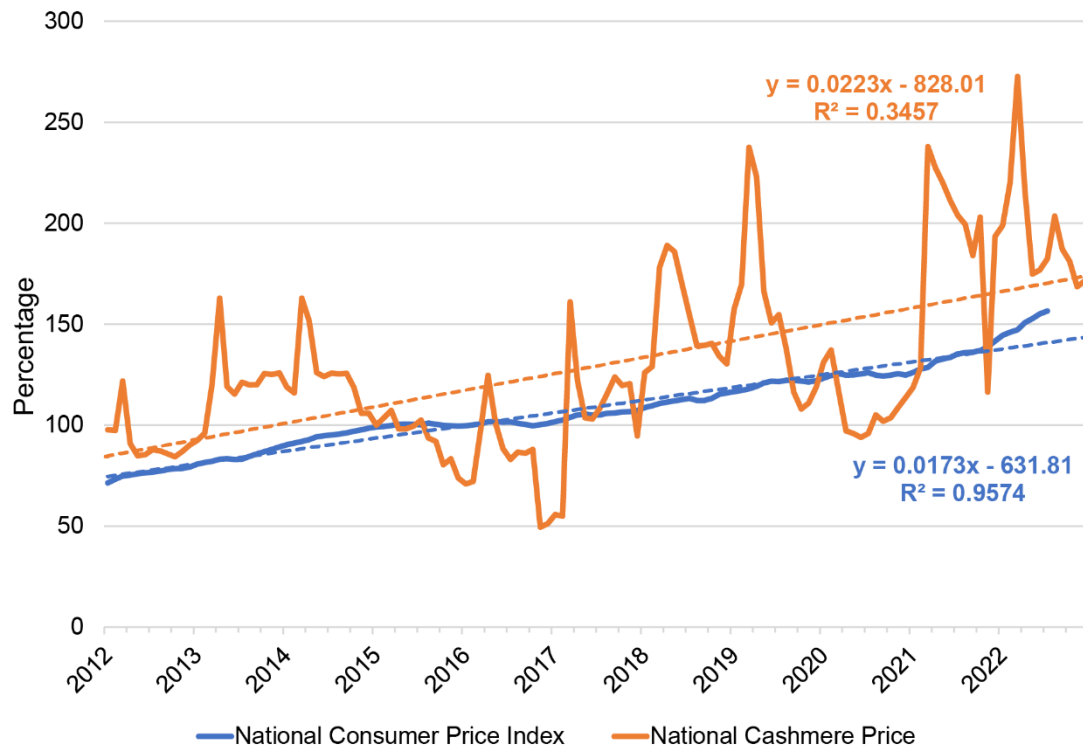


Figure 4.5: Trends of cashmere (Mongolian national mean orange), and consumer price index in percentage from 2012 until 2022; (Mongolian national mean in blue) 2015=100%. Trend lines are given in dotted lines. Data source: Mongolian Statistical Information Service, 2023

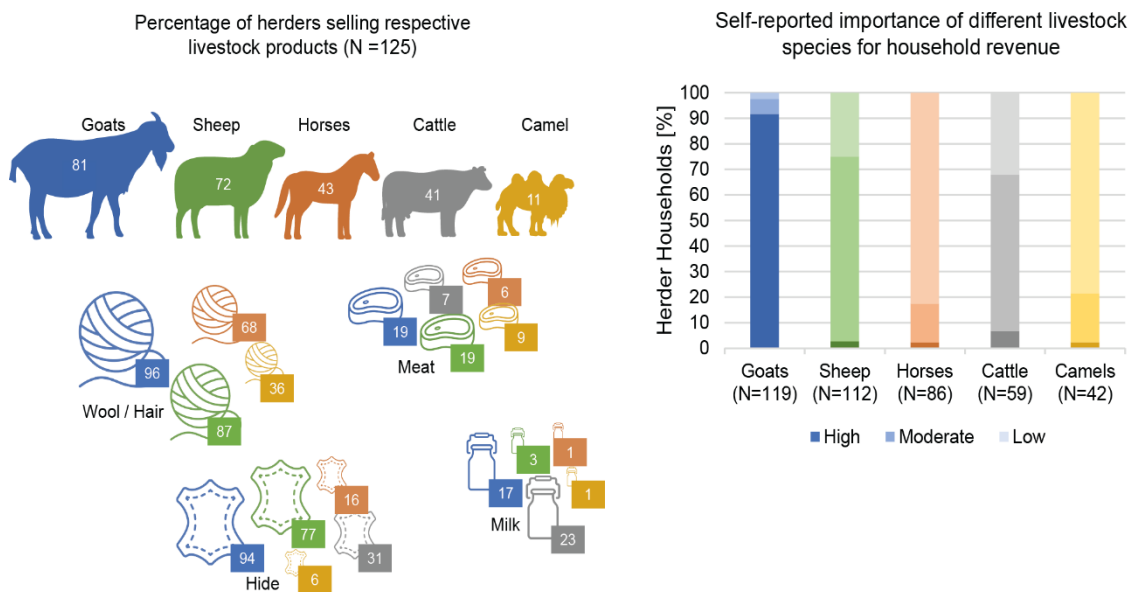


Figure 4.6: Left: Livestock and livestock products sold by herders in percentage (N=125) in and around the Great Gobi B SPA, Mongolia. Right: Self-reported importance of different livestock species for herder household revenue. Dark shades represent high, medium shades moderate and light shades low revenue gain

4.4.3 Daily and seasonal herder household division of labour

Herders have clear daily and seasonal routines in respect to household division of labour (Table C6 in the appendix). Herding small livestock is important year-round and is primarily the responsibility of men (83%). Most herders (72%) tend only their own livestock, while 25% also tended livestock of relatives. The most labour-intensive seasons are spring and summer (Table C6 in the appendix), when the herds give birth, cashmere is combed, and sheep and camels are sheared. Most daily and seasonal routines are conducted by household members (Figure C6 in the appendix) with assistance from relatives and neighbours during labour-intensive periods.

4.4.4 The future of the herder lifestyle

Local herder households have on average 3 (± 1 ; range 1-7) household members living at the herder camp in the Great Gobi B SPA, generally comprised of a married couple with pre-school or adult children who assist with herding and household responsibilities. At the time of our study, herder households in the Great Gobi B SPA had 460 children (mean per household = 4 (± 2)). Of those, 51 were pre-school age (mean = 1 (± 1)) living with the household, 143 of school age (mean = 2 (± 1)) living close to schools in the municipalities, and 28 children were enrolled at universities (mean = 2 (± 1)). Further, 61 adult children remained with their parents at the camp (mean = 1 (± 1)), 52 adult children owned their own livestock herds (mean = 2 (± 2)), and 125 (mean = 2 (± 2)) adult children had salaried jobs in municipalities.

During a focus group discussion with young herders they highlighted the advantages of a herding lifestyle (Table C4 in the appendix), including the freedom to move and unlimited access to the vast rangelands, improvement in access to media (TV, radio and internet), particularly for weather forecasts that can help determine when and where to graze livestock. Major challenges to life as a herder are mainly related to climate, namely extreme winters (“dzuds”) and drought summers, and limited infrastructure and poor access to public services (Table C4 and C5 in the appendix). Young herders participate much as the older generation in daily and seasonal tasks that are considered part of their traditional ecological knowledge (TEK; Table C5 in the appendix).

4.4.5 Herders’ involvement in protected area management

While 47% of herders consider living close to the Great Gobi B SPA as a livelihood advantage, the majority (50%) also stated that they follow the regulations and recommendations of the PA

management (Figure C1 in the appendix). Most herders (58%) claim they regularly participate in consultative meetings with the PA management, although only 29% felt their views are taken into consideration in decision-making. The majority (76%) also felt that the local herder community and the PA management should collaborate on the conservation of nature and use of natural resources. However, 82% of herders stated that cooperation between the PA management and the local communities needs to be improved to ensure environmental protection and sustainable use of natural resources.

The main challenges of herders living close to the Great Gobi B SPA were the limited pasture for small livestock (42%), limitations in pasture mobility and rotation (42%), misunderstandings with the PA management when migrating through the protected area (42%; Figure C2 in the appendix). About half of the herders (53%) pointed out that the information about meetings and workshops by the PA management is not distributed sufficiently, especially to herders staying very remotely. Several herders (42%) even said that there are no meetings organized to listening to the views of the local people, and that complaints and views of local people are not considered (45%; Figure C3 in the appendix). According to the herders (55%) there is a lack of information and understanding of the rights of the herder community regarding co-operation with the PA management and sustainable pasture use in the limited use zone of the SPA.

4.5 Discussion

4.5.1 Livestock trends

Data gathered from our focus group discussions and interviews indicated that local livestock trends in numbers and species composition in the Great Gobi B SPA roughly followed countrywide and regional patterns. With an average 653 head of livestock per household, average herd size in the Great Gobi B SPA is higher than other herding regions in Mongolia (Gombodorj, 2021).

4.5.2 Household economy

The sharp increase of livestock numbers in Mongolia over the last 20 years, especially of goats, is associated with increased international demand for cashmere wool and privatization of the market (Munkhzul et al., 2021; Rysbyek & Lei, 2022; Wei & Zhen, 2020). Our interviews revealed that herder households in the Great Gobi B SPA were fully dependent on livestock

production as their main income source, with cashmere as most important livestock product for income, similar to other regions in Mongolia (Gombodorj, 2021; Joly et al., 2019; Meurs et al., 2017). Other income possibilities are limited due to the harsh climate and the long distances between urban centres (IPECON / NZNI, 2003).

Despite local cashmere prices being slightly lower than the regional mean, local herders on average earned double the country's minimum wage from cashmere wool alone (Countryeconomy, 2018). In addition, the national cashmere price has increased by 119% over the last 10 years compensating for the 97% consumer price increase. However, local herders still earn 28% less than the annual average wage in Mongolia (Mongolian Statistical Information Service, 2023). Income from other livestock products is minimal and although meat and milk are used for own consumption, expenditure for food was the single most important household expense, followed by expenses for travel and transport, and clothing - together amounting to over 60% of household expenses. Herder households therefore have a very narrow economic safety margin and the high dependence on cashmere as main income source results in high household vulnerability to volatile prices (Marin, 2019; Murphy, 2018). Further, unpredictable weather conditions with an increased risk of extreme winter events have resulted in high livestock losses (Bayasgalan et al., 2006). These combined uncertainties are likely the motivation for herders to keep more livestock during favourable conditions instead of selling (Xu et al., 2019) and might explain why we found that herder households want to further increase their livestock numbers to reach a "good livelihood." Herders pay for social insurance and debts when they seasonally sell their livestock products (Bristley, 2021). If prices are low and livestock losses high, their narrow economic margin will not allow them to recover, as happened in the winter of 2009/10 (Kaczensky et al., 2011) when high livestock deaths due to the extreme cold ultimately forced herders to give up their herding lifestyle. To reach ecological and economic sustainability, herder households need additional and diversified income for maintaining or even reducing livestock numbers (Hu et al., 2019). In Mongolia, several international and national organisations focus on herder groups jointly managing pasture resources while also improving cashmere value-chains through fostering market access and increased livestock product prices (Addison et al., 2013; Okamoto & Jamsranjav, 2019). Some of those initiatives focus on a wildlife-friendly cashmere value chain (Okamoto & Jamsranjav, 2019), which could also be a strategy for herder households using the pastures of the Great Gobi B SPA. To secure and diversify herder household incomes in line with conservation aims, wildlife tourism has widely been practiced in PAs (Goodwin & Roe, 2001). However, we claim that more than just minor contributions must find their way to local communities to sustainably contribute to herders'

livelihoods (DeGeorges & Reilly, 2009; Nepal, 1997).

4.5.3 Herding tradition

We found that livelihood practices of herder households in the Great Gobi B SPA remain based on traditions and social networks centred around the extended family, as has been shown for other areas in Mongolia (Fernández-Giménez, 1999; Fernández-Giménez et al., 2017). During seasonal labour-intensive periods herder households are dependent on external support (Schlecht et al., 2020), which agrees with our findings that herds of more than 1,000 small livestock are difficult for a single herder household to manage, according to our interviews. Larger numbers of small livestock require herders to divide animals into multiple herds, thus requiring additional herders, a trend already reported from other regions of Mongolia (Mijiddorj et al., 2019; Murphy, 2015). This results in absentee and contract herding arrangements, which are becoming more common in Mongolia (Fernández-Giménez, 1999; Mijiddorj et al., 2019; Murphy, 2015). In Eastern and South Africa, such arrangements are often considered exploitative, with negative effects on livestock well-being and pasture health (Michler et al., 2019; Moritz et al., 2011). While we found that currently children are still valuable assistants in labour-intensive times for herders in the Great Gobi B SPA, maintaining the connection to their homeland (Sukhbaatar & Tarkó, 2018), we also saw a trend of the younger generation leaving the herding lifestyle.

4.5.4 Future of traditional herding

Overall, livestock herding is becoming less important for Mongolia's economy and GDP per capita, but low market prices for livestock products and poor market access might drive herders into increasing their livestock herd sizes (Xu et al., 2019). Locally, slightly more than half of adult children of herder households are employed in salaried jobs and no longer live as herders, reflecting a countrywide trend of rural-urban migration and rapid urbanisation in Mongolia over the last three decades (Dyer et al., 2022). Worldwide, herding as a livelihood is becoming less attractive to the young (Schlecht et al., 2020) who are moving to urban areas to seek wage labour or higher education (Fernández-Giménez et al., 2017; Park et al., 2017).

There also seems to be a growing gender gap in education (Ahearn, 2018; Steiner-Khamsi & Gerelmaa, 2008), which was mentioned in our focus group discussions and interviews, where our participants expressed agreement with the propositions that: “the education of female youths was prioritized over that of male youths, the latter being more often expected to continue as livestock herders,” and that this makes it “difficult for young men to find a partner and

continue a traditional family-centred herding lifestyle”. The long distances to urban centres also result in some herder households have to separate during winter, with women and school children staying in settled centres with schools while the men stay in the field to care for the livestock (Ahearn, 2018). During our household interviews, this practice was mentioned but was not yet a general trend. However, in our focus group discussion participants highlighted limited access to social services such as education and health care as a major challenge, which is in line with findings among nomadic herders in Africa (Dika et al. 2021; Gammino et al., 2020), South America (Caine, 2021), and other parts of Asia (Dyer & Rajan, 2023).

4.5.5 Herders and Protected Areas

Our results indicate that herders face challenges with PA management over pasture use, although they described living close to the Great Gobi B SPA as a livelihood advantage. In Africa, making use of pastures inside PAs is considered an important traditional pastoral coping strategy for environmental uncertainty (Butt, 2011) due to better pasture availability (Michler et al., 2019). In Mongolia, protected areas are often used as emergency pastures in times of limited resource availability during climate extremes (Bedunah & Schmidt, 2004; Hess et al., 2010). However, this also puts added pressure on threatened, rare wildlife populations, some of which are found only in PAs (Turghan et al., 2022), and might result in competition between herders with access permits to the PA and those without (Michler et al., 2019). This highlights the importance of good communication practices between PA management and the local pastoral community, which our interviewees perceived as insufficient. It should be noted, however, that most of the rangers in the Great Gobi B SPA do have a herding background and are well connected to the herding community. According to the PA rangers, the relationship and communication with the herding community was good. Being familiar with the seasonal routines of herder households is helpful for PA management to find the most suitable times to hold their meetings with herders. This should also be considered in the planning of scientific studies if the involvement of local herder households is intended. According to Abukari & Mwalyosi (2020) local communities in Ghana and Tanzania perceive the impact of PAs on their livelihoods and community development positively when PA governance is inclusive and engages with local communities requirements and preferences. We highlight that it is not the PAs responsibility to maintain or improve local herders’ livelihoods. However, research has showed that effective conservation is only possible when PA management is participatory and involving local communities (Nepal, 2002; Oldekop et al., 2016). According to our group expert interviews with the Great Gobi B SPA rangers, they participate in so-called Eco-clubs for children of the Great

Gobi B SPA buffer zone founded by WWF and UNDP (Swenson & Erdenebileg, 2012; WWF, 2018). Further, our expert group interviews revealed that around 20 herder households were engaged as community rangers reporting illegal activities and wildlife sightings. In addition, the PA management includes local herders in conservation activities such as wildlife counts (Ransom et al., 2012; Vogler et al., 2023), or the fencing of water springs, as reported by the rangers. We recommend the continuation or even intensification of such activities to strengthen the identification of the herder community with the PA conservation aims. This would also help herders and conservation managers to come to a mutually accepted understanding of rights and responsibilities within a PA (Molnár et al., 2016).

4.6 Conclusion

We conclude that herder households in the Great Gobi B SPA are reaching livestock herd sizes that are no longer manageable in the traditional way, threaten pasture health (Sainnemekh et al., 2022), and compete with wildlife populations (Berger et al., 2013). Therefore, we recommend a reduction in livestock numbers in and around the Great Gobi B SPA before pasture overexploitation jeopardizes biodiversity conservation and herder livelihoods. This can only be successful when local communities are involved in management decisions and profit directly or indirectly from the protected area. While a well-managed protected area can offer healthy pastures, job opportunities, and additional income from eco-tourism for some, PA management cannot solve the current dilemma of increasing livestock numbers to meet livelihood demands in the Great Gobi B SPA. National strategies are needed to enable local herding communities to maintain mobility, gain access to markets and social services, and diversify their economic basis to enhance their resilience to environmental and economic fluctuations. Involving local communities surrounding protected areas in participatory activities enhances the understanding and successful implementation of conservation aims. However, to successfully reduce livestock numbers to safeguard the pastures of the Great Gobi B SPA and the livelihoods of the herder households over the long-term, we conclude that government restrictions are inevitable.

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Chapter 5 Through the eyes of a herder – Pilot project on using herders as citizen scientists in Great Gobi B strictly protected area in Mongolia



Figure 5.1: Przewalski's horses in the Great Gobi B Strictly Protected Area in Mongolia (Photo by Lena Michler, 2017)

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Through the eyes of a herder – Pilot project on using herders as citizen scientists in Great Gobi B strictly protected area in Mongolia

Lena M. Michler^{1,2}, Anna C. Treydte^{1,3}, Buyantogtokh Dorjbat⁴, Petra Kaczensky^{5,6}

¹ Department of Ecology of Tropical Agricultural Systems (490f), Institute of Agricultural Sciences in the Tropics (Hans-Ruthenberg-Institute), University of Hohenheim, Stuttgart, Germany

² International Takhi Group, 8135 Sihlwald, Switzerland

³ Department of Physical Geography, Stockholm University, Stockholm, Sweden

⁴ International Takhi Group, Ulaanbaatar, Mongolia

⁵ Department of Forestry and Wildlife, Faculty of Applied Ecology, Agricultural Sciences and Biotechnology, Inland Norway University of Applied Sciences, Norway

⁶ Research Institute of Wildlife Ecology, University of Veterinary Medicine, Vienna, Austria

5.1 Abstract

Citizen science can contribute to conservation through data collection and increased public awareness. Especially in protected areas, where human and financial resources are often scarce, data collection with the help of locals has the potential to support monitoring. We tested paper diaries and small digital cameras as a tool to involve livestock herders as community-based rangers in the Great Gobi B strictly protected area, Mongolia. We report here the results of one herder who collected wildlife data over seven months as an example to show that his frequent wildlife sightings provide complementary information to data collected by rangers or scientists. However, using a diary requires a high degree of commitment by the herder. It further is labour intensive to transcribe the diary into a digital form, and the practicality of digital cameras is limited due to the lack of digital storage space. Therefore, we recommend testing this technology further by developing an application (app) to be used on the herder's smartphones, which can collect data and images and store it in a cloud database.

Key words: *Dzungarian Gobi, Pastoralism, Community-based Rangers, Wildlife Data, Protected Area*

5.2 Introduction

Worldwide, protected areas are key for conservation but they are often threatened by anthropogenic impacts such as illegal resource collection, poaching, and disturbance (Chanie & Tesfaye, 2015; Murguía et al., 2016; Rija et al., 2020). Therefore, monitoring of biodiversity and detection of illegal activities is an important task in protected areas globally (Kuiper et al., 2021). However, the majority of protected areas worldwide lack human and financial resources (Musika et al., 2022). . . Particularly areas, which are difficult to access, are often poorly monitored, potentially resulting in biased estimates of the status of biodiversity (Coad et al., 2019; Danielsen et al., 2005). Under such circumstances, citizen science can be an important source of information, and can contribute to conservation (Ellwood et al., 2017) through collection of data and increased public awareness (McKinley et al., 2017).

Mongolia has established 109 protected areas, covering about 20 % of its land surface, and the country plans to set aside additional areas to reach 30 % by 2030 (UNEP-WCMC, 2022). In rural Mongolia, nomadic pastoralism is still a key livelihood strategy (Mongolian Statistical Information Service, 2023), with livestock herders also being present inside most protected areas. In the Great Gobi B strictly protected area (GGB), located in the Dzungarian Gobi in south-western Mongolia, these semi-nomadic pastoralists and their livestock share space with a range of other large and medium sized mammal and bird species of international or national conservation concern, including two endangered wild equids, the Przewalski horse (*Equus ferus przewalskii*) and the Asiatic wild ass (*Equus hemionus*; McCarthy et al., 2022; Sundev & Leahy, 2019).

The livestock herders are allowed to use areas in the limited use zone for their winter camps and make use of additional sites in spring and fall, prior to their summer migration to the Altai range. These pastoralists are highly mobile and set up camps in remote parts of the protected area, especially in winter (Michler et al., 2022). . They regularly encounter wildlife while herding their livestock or while working around their camp sites and their observations have often been instrumental for rangers to find Przewalski's horses, which have moved beyond their usual range, discover carcasses of threatened wildlife, or detect illegal activities such as illegal mining. Some herders have also supported GGB as community rangers, participating in activities such as wildlife counts (Ransom et al., 2012). However, the full potential to use local pastoralists as citizen scientists (Cretois et al., 2020) has not yet been fully harnessed.

For this pilot project, we aimed to test the use of herder diaries in combination with small digital cameras as a tool to involve the local herder community more actively in biodiversity

monitoring and document which wildlife species are encountered when and where and how frequently.

5.3 Material and Methods

5.3.1 Study site

The GGB was established in 1975, recognized as UNESCO Man and Biosphere Reserve in 1991 (UNESCO, 2020) and doubled in size from originally 9,000 to 18,000 km² in 2019. Currently, 21 rangers are employed by the protected area to monitor and patrol the vast area (personal comment, Altantsukh Nanjid, director of the GGB, 2024).

Several wildlife species listed on the IUCN's Red List roam the Dzungarian Gobi such as the endangered Przewalski horse, the Asiatic wild ass ("khulan"), and the Goitered gazelle (*Gazella subgutturosa*) in the plains, and the Siberian ibex (*Capra sibirica*), the Argali sheep (*Ovis amon*), and the snow leopard (*Panthera uncia*; McCarthy et al., 2022) in the mountains.

Around 280 herders and their livestock, primarily (in decreasing order of importance) goats and sheep, cattle, horses, camels, and some yaks, have seasonal access to the limited-use zone from September until May. Only small livestock (goats and sheep) herds are guarded on a daily basis whereas large livestock species go unaccompanied and their whereabouts are only checked once daily, weekly, or sometimes even only monthly (Kaczensky et al., 2008; Michler et al., 2022).

5.3.2 Data collection by herders

In November 2018, we distributed blank "herder diaries" to ten interested livestock herders. They were asked to take this small booklet along on their daily herding routine (Table 5.1, Figure 5.2), and record all wildlife encounters, identifying species, number of individuals (adult and offspring), location, activity and condition of the wildlife species, as well as distance to the observer, and by what means of transport he/she was travelling. In addition, the participating herders were given digital cameras donated by private sponsors to take pictures of wildlife encounters.

Table 5.1: Recording table of herder diaries used for wildlife monitoring that was distributed to ten herders in the Great Gobi B Strictly Protected Area in Mongolia. The data have been collected by one herder only from December 2018 until July 2019

Date	Time	Animal species	Number of adult animals	Number of offspring	Name of location
	☐ Early morning ☐ Morning ☐ Noon ☐ Afternoon ☐ Early evening ☐ Evening ☐ Night	☐ Takhi ☐ Khulan ☐ Gazelle ☐ Argali ☐ Ibex ☐ Wolf ☐ Fox ☐ Snow leopard ...			
Distance from herder	Herder with flock	Herder alone	Herder by...	Activity of the animals	Condition of the animal
-----m	☐ Yes ☐ No	☐ Yes ☐ No	☐ Foot ☐ Horse ☐ Camel ☐ Motorbike ☐ Car	☐ Eating ☐ Drinking ☐ Standing ☐ Running ☐ Lying ☐ Attacking prey	☐ Healthy ☐ Weak ☐ Sick ☐ Dead

Огноо Date	Уул Mountain	Амьтдын Tайв Tайв	Бэлчээ Tайв Tайв	Төл Tайв Tайв	Тас Tайв Tайв	Мандал Хэргийн Байр	Мандал Хэргийн Байр	Мандал Хэргийн Байр	Мандал Хэргийн Байр	Мандал Хэргийн Байр	Мандал Хэргийн Байр	Мандал Хэргийн Байр
12/6	Хойд	Янгир	Бүдүүн 2	Төл 1	Тас 1	Алаг энгэр	50м	Тийм	Тийм	Тийм	Тийм	Тийм
12/7	Хойд	Гонд	Бүдүүн 1	Төл 1	Тас 1	Алаг энгэр	50м	Тийм	Тийм	Тийм	Тийм	Тийм
12/10	Шонд	Ирбэс	Бүдүүн 1	Төл 1	Тас 1	Алаг энгэр	50м	Тийм	Тийм	Тийм	Тийм	Тийм
12/15	Уд дунд	Янгир	Бүдүүн 7 тх 2	Төл 2	Тас 2	Алаг энгэр	50м	Тийм	Тийм	Тийм	Тийм	Тийм
12/16	Уд дунд	Янгир	Бүдүүн 8	Төл 4	Тас 4	Алаг энгэр	50м	Тийм	Тийм	Тийм	Тийм	Тийм
12/17	Уд дунд	Янгир	Бүдүүн 2 тх 1 төл 2	Төл 2	Тас 2	Алаг энгэр	50м	Тийм	Тийм	Тийм	Тийм	Тийм
12/18	Шонд	Ирбэс	Бүдүүн 1	Төл 1	Тас 1	Алаг энгэр	50м	Тийм	Тийм	Тийм	Тийм	Тийм
12/19	Уд дунд	Янгир	Бүдүүн 6 тх 2 төл 3	Төл 3	Тас 3	Алаг энгэр	50м	Тийм	Тийм	Тийм	Тийм	Тийм
12/21	Уд дунд	Янгир	Бүдүүн 1 ороо 1 төл 1	Төл 1	Тас 1	Алаг энгэр	50м	Тийм	Тийм	Тийм	Тийм	Тийм
12/22	Огноо	Янгир	Бүдүүн 3 тх 1	Төл 1	Тас 1	Алаг энгэр	50м	Тийм	Тийм	Тийм	Тийм	Тийм
12/23	Огноо	Янгир	Бүдүүн 4 тх 1	Төл 1	Тас 1	Алаг энгэр	50м	Тийм	Тийм	Тийм	Тийм	Тийм
12/24	Шонд	Ирбэс	Бүдүүн 1	Төл 1	Тас 1	Алаг энгэр	50м	Тийм	Тийм	Тийм	Тийм	Тийм
12/26	Огноо	Янгир	Бүдүүн 5	Төл 1	Тас 1	Алаг энгэр	50м	Тийм	Тийм	Тийм	Тийм	Тийм
12/30	Шонд	Ирбэс	Бүдүүн 1	Төл 1	Тас 1	Алаг энгэр	50м	Тийм	Тийм	Тийм	Тийм	Тийм
2019 1/2	Огноо	Янгир	Бүдүүн 5	Төл 1	Тас 1	Алаг энгэр	50м	Тийм	Тийм	Тийм	Тийм	Тийм
1/3	Шонд	Ирбэс	Бүдүүн 1	Төл 1	Тас 1	Алаг энгэр	50м	Тийм	Тийм	Тийм	Тийм	Тийм
1/4	Уд дунд	Янгир	Бүдүүн 20 төл 5	Төл 5	Тас 5	Алаг энгэр	50м	Тийм	Тийм	Тийм	Тийм	Тийм
1/6	Уд дунд	Янгир	Бүдүүн 10 төл 3	Төл 3	Тас 3	Алаг энгэр	50м	Тийм	Тийм	Тийм	Тийм	Тийм
1/8	Уд дунд	Янгир	Бүдүүн 5	Төл 1	Тас 1	Алаг энгэр	50м	Тийм	Тийм	Тийм	Тийм	Тийм
1/9	Уд дунд	Янгир	Бүдүүн 2	Төл 1	Тас 1	Алаг энгэр	50м	Тийм	Тийм	Тийм	Тийм	Тийм
1/11	Огноо	Янгир	Бүдүүн 2	Төл 1	Тас 1	Алаг энгэр	50м	Тийм	Тийм	Тийм	Тийм	Тийм
1/12	Уд дунд	Янгир	Бүдүүн 4 тх 2	Төл 2	Тас 2	Алаг энгэр	50м	Тийм	Тийм	Тийм	Тийм	Тийм
1/13	Уд дунд	Янгир	Бүдүүн 11 төл 8	Төл 8	Тас 8	Алаг энгэр	50м	Тийм	Тийм	Тийм	Тийм	Тийм
1/14	Огноо	Янгир	Бүдүүн 1	Төл 1	Тас 1	Алаг энгэр	50м	Тийм	Тийм	Тийм	Тийм	Тийм
1/15	Шонд	Ирбэс	Бүдүүн 1	Төл 1	Тас 1	Алаг энгэр	50м	Тийм	Тийм	Тийм	Тийм	Тийм
1/17	Шонд	Ирбэс	Бүдүүн 1	Төл 1	Тас 1	Алаг энгэр	50м	Тийм	Тийм	Тийм	Тийм	Тийм
1/19	Огноо	Янгир	Бүдүүн 1	Төл 1	Тас 1	Алаг энгэр	50м	Тийм	Тийм	Тийм	Тийм	Тийм
1/20	Уд дунд	Янгир	Бүдүүн 1	Төл 1	Тас 1	Алаг энгэр	50м	Тийм	Тийм	Тийм	Тийм	Тийм

Figure 5.2: Example page of the herder diary that had been filled out by a herder in the Great Gobi B strictly protected area in Mongolia between December 2018 and July 2019.

5.3.3 Mobility data of herder and his livestock herd

As described in (Michler et al., 2022), we equipped one male goat of the herder with a light-weight GPS collar (CatLog Gen2, Perthold Engineering LLC, Dallas, TX, USA) to document the mobility pattern of his mixed goat and sheep herd. The GPS collar was deployed during the time when the herder recorded wildlife in his herder diary. We visually identified herder camp locations through dense clusters of GPS points, as described in more detail in (Michler et al., 2022).

5.4 Results

One livestock herder named Davaatseren Tangad (Figure 5.3) filled in the herder diary on a regular basis over a 220-day period between December 2018 and July 2019. Other participants only recorded observations very irregular and sketchy, making it difficult to draw any conclusions and, hence, we focused on this one successful long-term documentation. Only one of the participants recorded a wildlife photo, due to problems with battery loading and data download. Hence, our report represents a basic demonstration that these diaries can be a highly helpful tool, and we discuss further options to enhance participation and ease of reporting.



Figure 5.3: The herder Davaatseren Tangad (second from the left) with the first author Lena Michler and four other herders in the Great Gobi B strictly protected area in Mongolia. The photo was taken during a field workshop in August 2019 (Photo by Anna C. Treydte, 2019).

The herder made a total of 179 wildlife observations on 100 different days and at 42 different locations. The most commonly observed wildlife species were Siberian ibex, followed by

Goitered gazelle, khulan and wolf (*Canis lupus*; Table 5.2). The GGB's flagship species, the Przewalski horse, was only encountered twice (Table 5.2). Most wildlife sightings occurred in April 2019 and least in February 2019 (Table 5.2). During summer (June – July) the herder left GGB but continued his wildlife observation.

The participating herder observed 59 groups of Siberian ibex, with the biggest numbering 50 animals in total (20 adults and 30 kids), other groups were smaller numbering on average of 9 (± 9) animals. He also observed 32 groups of Goitered gazelles, ranging between 1 to 20 animals, with an average group size of 5 (± 4) animals, and 27 groups of khulan with an average group size of 10 (± 8) and 30 animals in the largest group (20 adults and 10 foals). Further, he observed 25 groups of wolves, ranging between 1-8 animals. He recorded 18-times the sighting of a Corsax fox (*Vulpes corsac*) and 4-times a snow leopard. On 4 occasions, the herder observed Altai snowcocks, once claiming to have seen 20 adults. He encountered 3-times the Eurasian lynx, 2-times Tarbagan marmots (once two at the same time), 2-times the Marbled polecat, and once the Tolai hare. On 2 occasions, he also saw Przewalski's horses, once a group of 14 animals (including 4 foals) and once a single Przewalski's horse.

The herder was on average 285 (± 217) m away from the animal(s) he observed, with a maximum distance of 900 m and a minimum distance of 20 m (Table 5.2). He came closest to the Siberian ibex and observed the Goitered gazelle and Siberian ibex from the farthest distance. In 50% of the wildlife sightings, the herder was walking, followed by riding on horseback (34%), riding on his motorcycle (12%), or driving his car (5%). In 90% of the wildlife sightings, he was with his livestock. The most frequent behaviour of observed wildlife was running (40%), followed by eating (24%), lying (17%), standing (10%), and walking (7%). Only one animal each were observed drinking and playing. Two Corsax foxes, one Siberian ibex and one Goitered gazelle found dead. One Siberian ibex, one Goitered gazelle and one Marbled polecat were observed to be weak.

Table 5.2: The number of wildlife species sightings per month and self-reported distance (mean $\pm$ standard deviation and range) of the herder from wildlife in meter as recorded by a herder in the Great Gobi B strictly protected area in Mongolia, from December 2018 until July 2019

Wildlife Species		Wildlife sightings per month								Distance from herder		
Species	Scientific Name	Total	Dec	Jan	Feb	Mar	Apr	May	Jun [*]	July [*]	Mean $\pm$ SD [m]	Range [m]
Siberian ibex	<i>Capra sibirica</i>	59	7	18	5	12	5	4	5	3	247 $\pm$ 238	20 - 900
Goitered gazelle	<i>Gazella subgutturosa</i>	32	1			10	12	8		1	305 $\pm$ 203	50 - 900
Asiatic wild ass	<i>Equus hemionus</i>	27				9	11	7			380 $\pm$ 199	50 - 800
Wolf	<i>Canis lupus</i>	25	1	6	2	1	6	4	2	3	326 $\pm$ 189	100 - 500
Corsax fox	<i>Vulpes corsac</i>	18	1		1	1	7	6	1	1	181 $\pm$ 135	50 - 500
Snow leopard	<i>Panthera uncia</i>	4	2	2							125 $\pm$ 119	50 - 300
Altai snowcock	<i>Tetraogallus altaicus</i>	4							2	2	650 $\pm$ 173	500 - 800
Eurasian lynx	<i>Lynx lynx</i>	3	1	2							117 $\pm$ 76	50 - 200
Tarbagan marmot	<i>Marmota sibirica</i>	2							2		150 $\pm$ 71	100 - 200
Marbled polecat	<i>Vormela peregusna</i>	2							1	1	300 $\pm$ 141	200 - 400
Przewalski horse	<i>Equus ferus przewalskii</i>	2					1	1			300 $\pm$ 283	100 - 500
Tolai hare	<i>Lepus tolai</i>	1							1		200	200
	Total	179	13	28	8	33	42	30	13	11		

*Wildlife observations outside GGB

Most wildlife was observed around spring camps located inside or directly adjacent to the Great Gobi B SPA border. In this area, Asiatic wild ass, Goitered gazelle, Przewalski horse, Corsax fox, and wolf were observed, as well as once Siberian ibex (Figure 5.4). In the summer camp, located within the Altai Mountains outside of the GGB, Altai snowcock, Tarbagan marmot and Marbled polecat were observed, along with Siberian ibex, wolf, Corsax fox and Goitered gazelle. During winter, at the winter camp in the mountainous regions in the South of the GGB, mainly Siberian ibex and wolves were observed but also Snow leopard, Eurasian lynx and Corsax fox (Figure 5.4). The herder observed wildlife either from horseback or by walking, mainly around the camp site or while herding livestock. Sightings further away from camps were made while driving a car or motorbike.

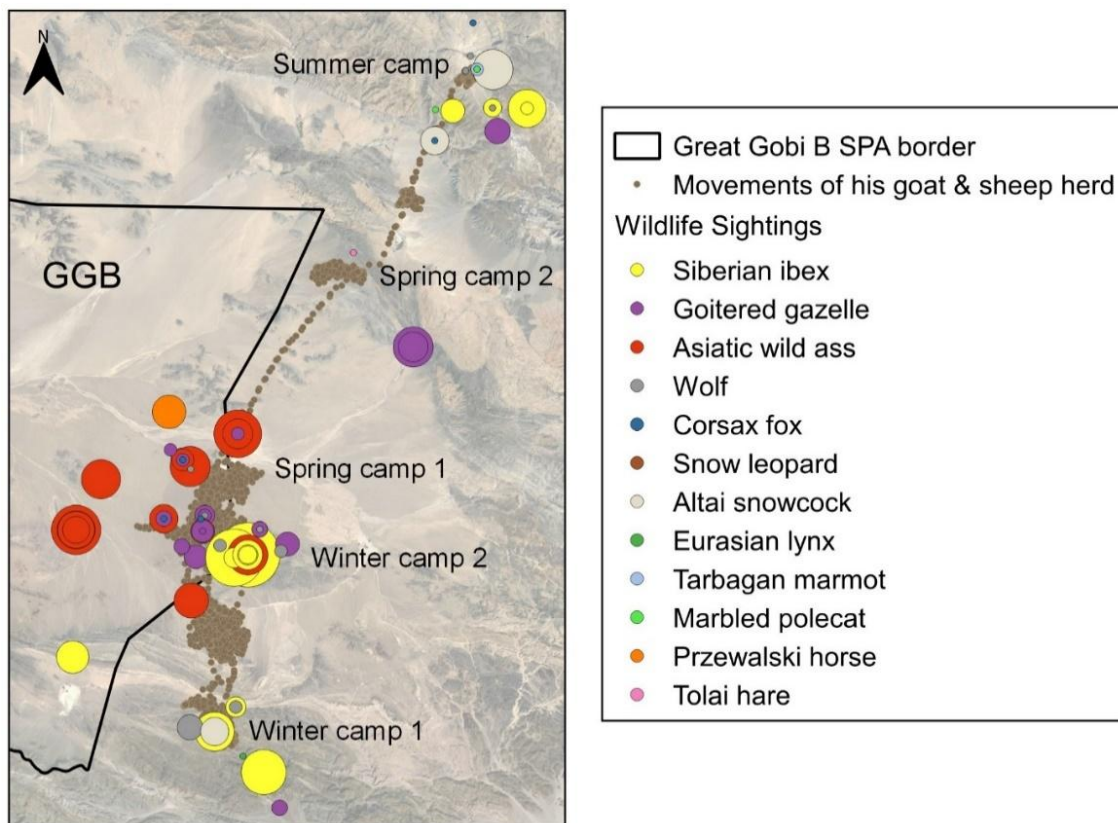


Figure 5.4: Wildlife sightings described by a herder participating in our study in his herder diary in the Great Gobi B strictly protected area in Mongolia, from December 2018 until July 2019. The herder's camps are marked and the movements of his goat and sheep herd are shown in brown. The observed wildlife is sorted from most frequent sighting to the least. Each colour represents a different wildlife species and the size of the point shows the group size of the observed wildlife species, respectively.

Unfortunately, the participating herder did not take any photographs of wildlife encounters, primarily because he had no possibility to download and store the data. The other participants faced the same problem and, as a result, only one very spectacular photo of a close encounter by one herder on horseback with a snow leopard was taken and saved (Figure 5.5).



Figure 5.5: Photo of a Snow leopard (*Panthera unica*) taken by herder Bayar Khadbaatar at close range from horseback in the Great Gobi B strictly protected area in Mongolia (the shadow on the left shows the herders' horse). The photo was taken in April 2021 in Shiree Khairkhan by Bayar Khadbaatar.

5.5 Discussion

The overall aim of this pilot study was to identify the potential of herder diaries as a suitable citizen science tool for collecting complementary wildlife observation data in the GGB. We exemplarily reported the results from one herder, who successfully recorded wildlife observations over a 220-day period. Our study shows the data collection potential and we discuss how to further facilitate this kind of reporting to enhance participation of local people.

Our pilot study showed that herder diaries can document many observations and provide an interesting data base that can complement data collected by park rangers or scientists. Nomadic herders share space with wildlife year-round (Dyson-Hudson, 1980) and, therefore, frequently encounter wildlife during their every-day life. If they record these wildlife observations continuously, their data not only documents species presence, but also provides information about the encounter rates of livestock and wildlife. The latter is of high importance in the context of wildlife-livestock competition and conflict, as well as disease transmission. Furthermore, citizen science approaches are important for including local people in research and monitoring

activities. These approaches open up a dialogue between different perspectives, including traditional and local knowledge, and contribute to a better understanding of, and trust in, scientific results by local people (McKinley et al., 2017).

In Mongolia, citizen science was used only by a few non-governmental organizations such as the World Wildlife Fund (WWF), who worked with volunteer rangers focusing on snow leopards (WWF, 2022) until recently. Also, the platform Public Lab Mongolia (2024) focused on environmental justice. Several organizations, such as UNICEF (Bayasgalan, 2023) and WWF (WWF, 2018) have further established so-called Eco-clubs to involve children in environmental education and protection. Children of Eco-clubs around GGB frequently visit the protected area and spend a day with rangers who show them their daily work routines.

Our herder diaries were an approach to also involve local adults in the monitoring routines of the GGB. However, the fact that only one out of ten herders collected wildlife data over a longer time period, and that only one photograph of a wildlife encounter was recorded shows that our approach with a paper-based herder diary and digital cameras was not optimal. The problems with the digital cameras should have been anticipated, as photographs could be a powerful tool to verify wildlife observations or rare species. In the case of our participating herder, the observation of 20 adult Altai snowcock seems rather unusual and there may be a problem with species identification, either on the herder's side or on the translation site. With a photograph, it may have been possible to resolve the uncertainty about this observation. Both issues, the unpopularity of the paper diary and the problems with the digital camera, could be solved by using phone based apps, which upload data and images taken by smartphones. These apps have become a trusted tool in local herders' daily life (Zagdragchaa & Ykhanbai, 2012), and a cloud-based database can be used once there is phone coverage (Hijaba et al., 2013).

According to Batsaikhan et al. (2023) the availability of online citizen science platforms in Mongolia has increased within the last ten years, driven by international projects. Nowadays, flora and fauna data is collected frequently by domestic platforms such as "Mongolian Biodiversity" with almost 3,000 users (Baigali, 2024). Further, worldwide online platforms such as iNaturalist (2024), where observations can be shared to contribute to biodiversity science globally, are available. We believe that there is also large potential of such approaches at the level of protected areas, particularly when projects are adapted to local needs (Batsaikhan et al., 2023). In Mongolia, where one-third of the population is still living as nomadic pastoralists (Mongolian Statistical Information Service, 2023) and share space with wildlife, a common understanding for conservation aims and monitoring is needed (Jamsranjav et al., 2019). Digital

herder diaries can act as a tool to create a common understanding shared by protected area staff, researchers, governmental monitoring agencies and local people, and can help integrate local people into conservation activities.

Freely available apps such as SMART (SMART, 2024) or BIOSAN (WWF, 2023) are already used for biodiversity monitoring in Mongolia and others such as KOBOTOOLBOX (KoboToolbox, 2024) or OPENBIOMAPS (OpenBioMaps, 2024) offer further opportunities. Since the year 2023, rangers in GGB have started using SMART for reporting to the ministry (personal communication with Altansukh Nanjid, director of the GGB, 2024). A similar platform using SMART or another app could be established to collect citizen science data in protected areas such as GGB.

5.6 Conclusion

Herder diaries show a great potential for collecting complementary wildlife observations in remote protected areas and for including local herders in conservation activities. We conclude that App-based data collection with the use of smartphones will become highly relevant in the future for such collaborations between researchers, conservationists and local people.

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Chapter 6 Discussion

6.1 General Discussion

In this thesis, I focused on adaptation strategies of Mongolian herders to environmental and socio-economic changes. Based on my results, I discuss herder household mobility, livestock grazing impacts on pastures, socio-economic challenges of herder households, and the interaction of protected area (PA) management and herder households in the Great Gobi B Strictly Protected Area (SPA; Figure 6.1). Pastoralism is the most common land-use form worldwide (R. S. Reid et al., 2014), however, rangeland health and biodiversity are under threat due to increasing livestock numbers (Thornton, 2010), socio-economic changes (Manzano et al., 2021b) and climate change (Godde et al., 2020). In this thesis, I combined multiple ecological and socio-economic datasets at landscape, regional, and local scale to provide insights into small livestock grazing and herder livelihoods in a PA in Mongolia. The findings of this study can help PA managements and policy makers to develop measures to consolidate nomadic pasture use and PA management.

My main findings in chapter 2 were that herders in the Dzungarian Gobi have optimized pasture use by practicing high travel mobility with frequent camp moves according to vegetation availability for their livestock. I found that herders selected their camp sites based on forage quality for their livestock. However, I detected only limited evidence for grazing impacts on vegetation around herder camps, which leads me to conclude that this high mobility resulted in optimized pasture use (Chapter 2). Additionally, I found that livestock herd mobility and herders' camp use duration was based on available plant biomass and seasonality. In chapter 3, I debated that the high flexibility of herders to change camps and adapted grazing mobility to plant biomass availability likely counteracts pasture overuse. I highlighted that herders embarked not only on horizontal but also on altitudinal migration between the winter camps in the Gobi plains and alpine summer pastures in the Altai mountains to provide their small livestock with nutritious vegetation by surfing the so-called green-wave and taking advantage of climate differences (Chapter 3). However, this balanced pasture use is threatened by increasing livestock population resulting in increased grazing pressure on the vegetation. I described in chapter 4 that herder households are under an economic pressure to further increase their livestock numbers to maintain their livelihoods. I found that herder households' main income source was from the cash crop cashmere, prices of which are undergoing high global market fluctuations, pinpointing towards herders' dependency on the market economy. However, their daily and seasonal routines were still family-centred and based on traditions they used during a time they were still

subsistence pastoralists. The trend of urbanisation and leaving the pastoralist lifestyle in this very remote region was, however, present in my study, and this indicates further changes to pastoral livelihood in the near future (Chapter 4). The access to pastures in the PA was perceived very positively by the herders I interviewed, although they mentioned that communication between the PA management and the herding community needs to be improved (Chapter 4). Herders in and around PAs can be helpful allies in conservation as I found that herders can be actively involved in collecting wildlife observation data (Chapter 5).

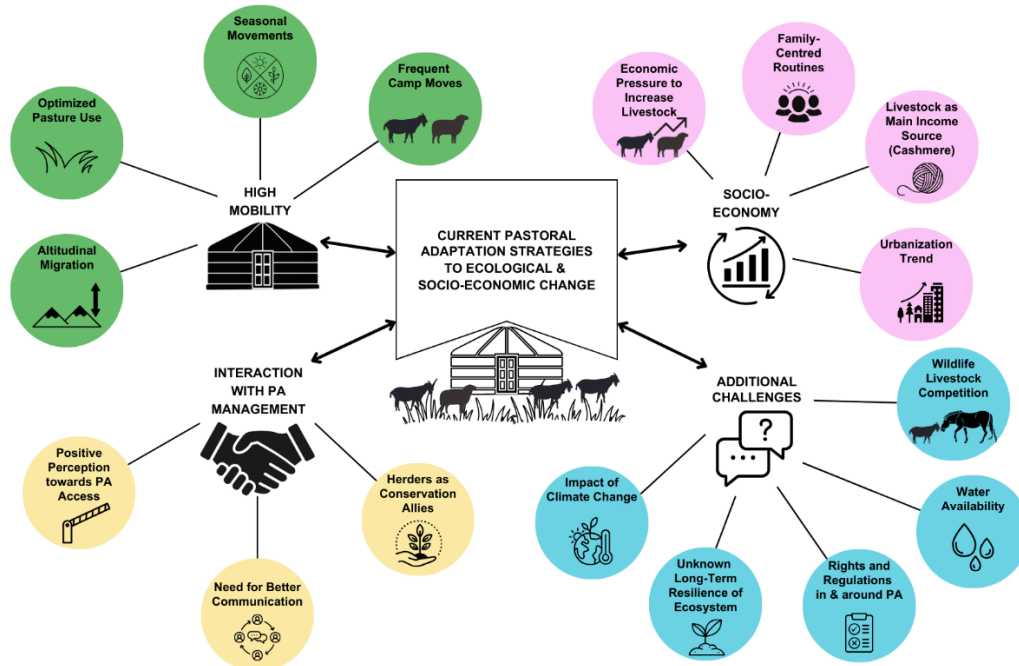


Figure 6.1: Main results overview of this thesis: The graph shows an overview of adaptation strategies of herders in the Great Gobi B Strictly Protected Area in Mongolia to ecological (green) and socio-economic change (purple), additional challenges (blue) and the interaction between the local herding community and the protected area management (yellow).

In this overall discussion, I address the interlinkages, importance, and limitations of this study, and highlight future research needs. I discuss nomadic pasture use in a strictly protected area in terms of ecological impact on the ecosystem, socio-economic importance for herders' livelihoods and conservation aims (Figure 6.1). I also describe the importance of a holistic view on the integration of human land use in nature conservation (Chapter 6.3). Further, I highlight additional challenges of herding in the Great Gobi B SPA and propose recommendations for more sustainable pasture use in and around PAs.

6.2 Ecological and Socio-Economic Adaptation Strategies of Herders in the Dzungarian Gobi

6.2.1 Optimized pasture use due to high travel mobility, flexible grazing patterns and altitudinal migration following plant biomass availability

The findings of this thesis underscore that herders in the Dzungarian Gobi adjust their mobility patterns, camp selection, and livestock grazing strategies in response to the spatial-temporal availability of plant biomass, reflecting their adaptation to resource heterogeneity (Briske et al., 2020). In this regard, mobility and flexibility emerged as important adaptive strategies for herder households in the Dzungarian Gobi, a practice common in Mongolia (Fernandez-Gimenez & Swift, 2003). The mobility patterns observed in this study were characterized by altitudinal migration between the Gobi plains in winter and the Altai mountains in summer. Whereas the location of winter camps was more or less fixed, spring, summer, and autumn camps location exhibited greater flexibility. Consequently, herders in the Great Gobi B SPA employed a mixed strategy of nomadism and transhumance (Behnke et al., 2011; Blench, 2001; Luick, 2008). My data revealed that herders in the Great Gobi B SPA exhibit high mobility, with frequent camp relocations, averaging nine times per year. This level of travel mobility was considerably higher than in other regions of Mongolia (Ahearn, 2018; Lkhagvadorj et al., 2013a), and other arid regions, for example in South Africa (Michler et al., 2019; Samuels et al., 2019) or Pakistan (Joshi et al., 2013). I found that the cumulative annual movement distance of small livestock herds was 3,520 km, which is comparable to that of the Mongolian gazelle (*Procapra gutturosa*) known for its extensive migration patterns (Dejid et al., 2022; Joly et al., 2019).

My study analysis further indicated that plant biomass availability was the primary determinant for herders' decision to relocate from the desert-steppe region of the Great Gobi B SPA to the higher-altitude pastures during the summer months, outside the PA (Figure 6.2). Consistent with the "forage-maturation-hypothesis" (Hebblewhite et al., 2008), herders revealed in my interviews that the transition to spring camps was triggered by snowmelt and the onset of vegetation growth. According to herders, the high plant biomass availability at autumn camps is crucial for enabling livestock to gain weight, similar to findings in the Mongolian steppe (Behnke et al., 2011). Given the short vegetation period in Mongolia (Dorjsuren et al., 2023), it is vital for livestock health to gain sufficient fat reserve to survive the long and cold winters. Regarding the decision when to move to the winter camps, herders in my study reacted very flexible based on pasture availability around autumn camps and on weather conditions. These

findings contrast with those of Behnke et al. (2011), who suggested that herders typically relocate to winter camps with the first snowfall and the onset of colder temperatures. Additionally, my study revealed that small livestock in the Great Gobi B SPA spent over 50% of the day at the herder camp, primarily resting. Presence at the herder camp was nearly twice as long during the winter compared to spring and autumn; so that grazing pressure around the winter camps was similar to that observed in the other two seasons despite the longer presence at the winter camp locations. During winter, livestock reduce their movement and grazing activities due to colder temperatures and shorter daylight hours (Adams et al., 1986; P. Liu et al., 2019). Consequently, I found that the time livestock spent grazing in more distant pastures increased with rising temperatures and plant biomass availability, while the duration of camp use also increased with greater plant biomass but was also influenced by season. Compared to small livestock in other regions of Mongolia and Inner Mongolia (Kawamura et al., 2005; Tsevegemed et al., 2019) the overall grazing mobility of small livestock in the Great Gobi B SPA was slightly lower.

Furthermore, I found that the altitudinal migration of herders between the Gobi plains during winter and the Altai mountain pastures in summer enables livestock to access more nutritious vegetation by following the vegetation green-up (Bischof et al., 2012; Fryxell & Avgar, 2012). My remote sensing data on the enhanced vegetation index (EVI) revealed the highest vegetation availability in the alpine pastures and the lowest in the winter camps on the Gobi plains, reflecting a clear altitudinal vegetation gradient also described by Chuluunkhuyag et al. (2021). This increased forage availability on the Altai mountain pastures may explain why I observed that local sheep and goat breeds were slightly heavier and lost less weight during winter compared to other small livestock in Mongolia that do not engage in altitudinal migration (Jamsran et al., 2018; Jargalsaihan et al., 2021; Tumurjav, 2003). In addition, herders identified several benefits of altitudinal migration, including reduced exposure to biting insects, better access to rivers and streams, and the opportunity to escape the extreme summer heat of the Gobi plains, thus mitigating heat stress for their livestock (Figure 6.2; Goma & Phillips, 2022). This highlights how altitudinal migration contributes to the fitness of small livestock and, consequently, enhances livestock production, a livelihood upon which most herders in this study were fully reliant.

In many arid rangeland systems, the population dynamics of both wild and domestic herbivores are closely tied to key resources such as forage and water (Illius & O'Connor, 2000). However, the harsh weather conditions further influence camp location with herders selecting for areas which provide also shelter from winter storms. Herders in my study spent the longest time at these winter camps, which therefore represent a bottleneck in the system. Consequently, it is

crucial to closely monitor winter camps within the Great Gobi B SPA, paying particular attention to stocking densities and ensuring they are carefully regulated.

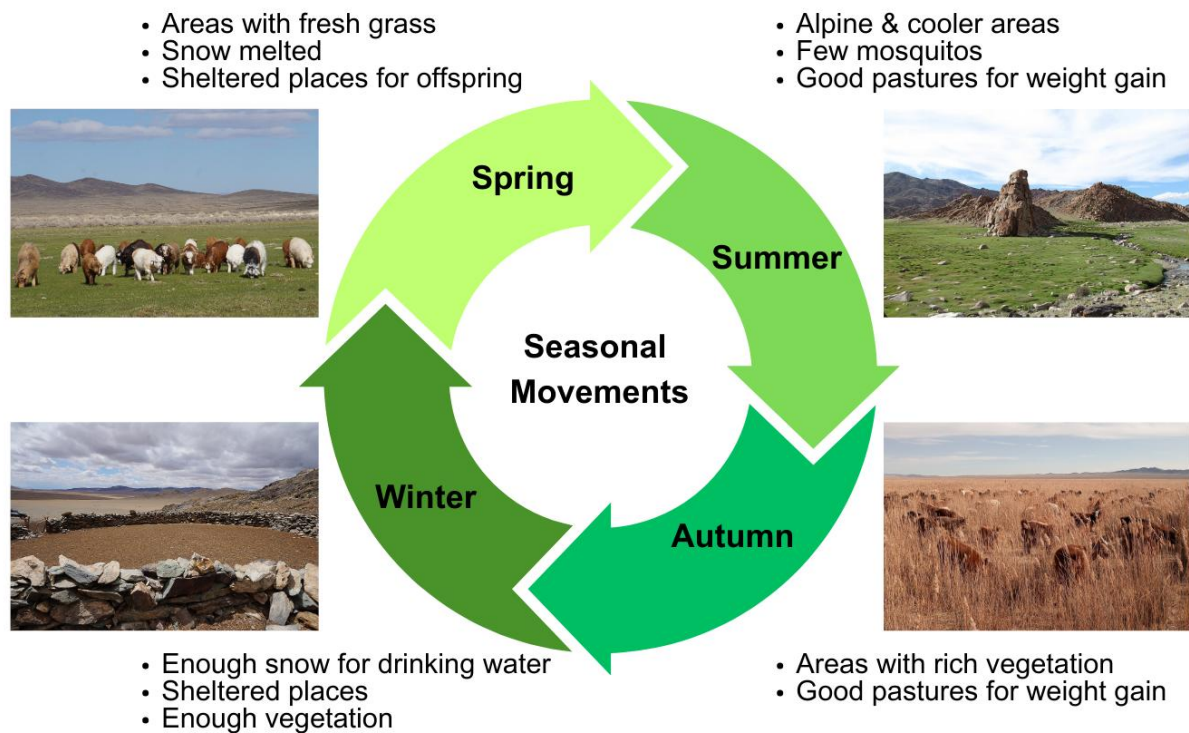


Figure 6.2: Seasonal movements of herders and their small livestock herds in the Great Gobi B Strictly Protected Area in Mongolia according to herder household and focus group interviews (Photos by Lena Michler, 2018, 2019)

Herders in my study selected the most nutritious grass communities for their small livestock herds based on their traditional ecological knowledge (TEK; Meuret & Provenza, 2015). Nutritional analysis showed that *Stipa* spp.- which was the plant community preferred by herders - had the highest nutrient content. This finding aligns with previous studies by Fernandez-Gimenez (2000) and Joly et al. (2013) on other Mongolian pastures. As expected, plant cover and species richness around herder camps were relatively low, consistent with the characteristics of desert-steppe and desert communities in the Dzungarian Gobi (Chuluunkhuyag et al., 2021). The intensity of livestock use around herder camps likely contributed to increased grazing pressure, trampling, and nutrient inputs through urine and dung in the vicinity of the camps (Andrew, 1988; Hess et al., 2020; Sasaki et al., 2008). I anticipated that this grazing intensity would be reflected in vegetation patterns and nutrient inputs in the soil, forming a gradient away from the camps. However, the grazing intensity did not correlate with significant differences in vegetation characteristics. I observed only minor variations in plant species richness, plant biomass, and cover as distance from the camps increased. Additionally, I noted a slight trend

toward higher nutrient content in soils closer to the camps, although these differences were not statistically significant (Michler et al., in preparation).

In 2018, autumn rainfall in my study caused more noticeable fluctuations in plant biomass availability between sampling periods than across the distances from the camps. These unusual autumn rains prompted a second green-up, which led some herders to move to their winter camps, even though pastures around their autumn camps were still in good condition. I conclude that precipitation may influence vegetation parameters more significantly than grazing impacts, consistent with the non-equilibrium nature of the Gobi rangelands (Fernández-Giménez & Allen-Diaz, 1999; Wesche et al., 2010). Under climate change, the spatial-temporal distribution of precipitation in Mongolia is expected to change even more (Xia et al., 2022). The potential impacts of these anticipated climate changes on spatial and temporal vegetation availability, and their subsequent effects on pastoral mobility patterns within this non-equilibrium system, remain uncertain and warrant further investigation.

I conclude that herders in the Dzungarian Gobi have optimized pasture use by adapting to changes in plant biomass availability at both landscape and local scales, and by embarking on altitudinal migration. Such ecological adaptation strategies by herders are for example found in the Maasai land-use systems dividing rainy and arid rangelands (Baumgartner et al., 2024). While no evidence of pasture degradation was observed during this study, it is important to note that the study duration was limited to two years. Long-term monitoring is essential to detect potential changes in vegetation characteristics over time. Given the ongoing trend of increasing livestock numbers in Mongolia (Mongolian Statistical Information Service, 2023) and the anticipated impacts of climate change (Tugjamba et al., 2023), effective pasture management is critical. This necessitates the implementation of monitoring and control mechanisms for livestock populations, grazing patterns, and vegetation assessments. As pastoral travel mobility is declining globally (Adriansen, 2008; Liao et al., 2020), maintaining mobility presents a significant challenge for herders in and around the Great Gobi B SPA, as well as for the management of the PA. I conclude that sustainable pasture use in these arid systems is contingent upon a high degree of mobility and flexibility, in combination with adapted livestock stocking densities. Therefore, policies and land-use management decisions within and around PAs should prioritize mobility and flexibility to support the long-term sustainability of pastoral practices and the ecosystems.

6.2.2 Appropriate livestock numbers for pasture health

Mongolia's transition from a centralized socialist system to a market economy led to the privatization of the livestock sector and resulted in record-high livestock numbers (Mongolian Statistical Information Service, 2023; Tumur, 2021). This trend, which was also evident in my study, highlights the growing need for effective control or regulation of livestock populations, particularly in PAs, where avoiding negative impacts on wildlife populations (Salvatori et al., 2021, 2022; Soofi et al., 2018) and maintaining pasture health (Hilker et al., 2014; Liu et al., 2013) for biodiversity conservation are key conservation goals (Figure 6.3).

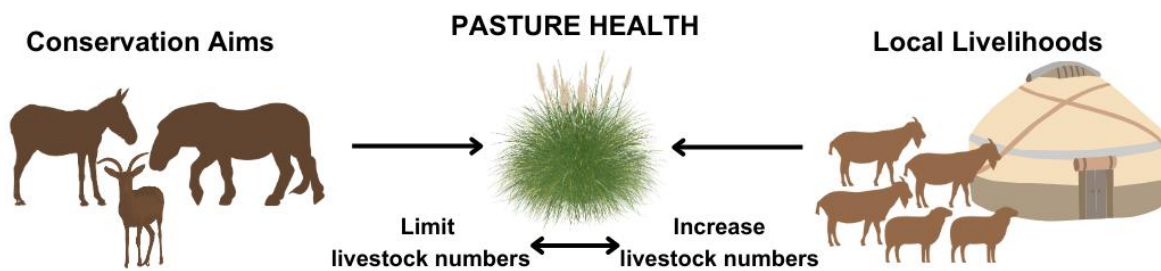


Figure 6.3: Linkage between pasture health, conservation and human land use through local livelihoods, with sometimes contrasting aims for livestock numbers.

However, determining the sustainable number of livestock that a system can support is a challenging task, as ecological tipping points are often difficult to detect (Fernández-Giménez et al., 2017), particularly in the context of climate change (Brovkin et al., 2021). The concept of “carrying capacity”, frequently used in rangeland and wildlife management (Chapman & Byron, 2018), refers to optimal stocking rates for pastures. Generally, carrying capacity is difficult to define (Dhondt, 1988; Ungar, 2019), and applying this concept in arid areas is unsuitable and can only be used to define long-term averages (Briske et al., 2020).

Carrying capacity is based on equilibrium models, which do not account for the inherent heterogeneity and temporal variability of resources typical in arid systems (Briske et al., 2020). Furthermore, this concept was developed in a Western contexts and has been applied globally to diverse pastoral systems (Sayre & Fernandez-Gimenez, 2003), sometimes resulting in misapplications and the failure of development programs (Sayre, 2019). Although the carrying capacity concept continues to inform policy and land management decisions (Cheng et al., 2017; Wang et al., 2024), these decisions are often made over much shorter time frames than are needed to assess significant changes in vegetation and ecological conditions (Vetter, 2005). Thus, I argue that the application of the carrying capacity concept is impractical in arid regions

such as the Dzungarian Gobi, where resource heterogeneity and temporal variability are high (Briske et al., 2020; Sayre & Fernandez-Gimenez, 2003). I found that, similar to countrywide trends, livestock numbers are on the rise in the Dzungarian Gobi. However, according to Wang et al. (2024) stocking densities observed in this area are relatively low compared to other regions in Mongolia. The low productivity, remote location of the Great Gobi B SPA, combined with only seasonal pasture access (Sansarbayar, 2019) and the high mobility and flexibility of herder households - highlighted by my study - may explain the lower stocking densities. Nevertheless, long-term vegetation assessments in the Great Gobi B SPA, along with monitoring of various ecological, social and economic parameters (Wang et al., 2024), including wildlife presence (Ren et al., 2021) are essential to manage pasture use more sustainable.

The Mongolian government collected taxes on livestock until the severe winter of 2009/2010 (Undargaa, 2023). Recognized as most harmful to pastures, goats were taxed at the highest rate among all livestock species. However, the taxation rate was too low to effectively achieve the goal of reducing livestock numbers (Oniki et al., 2018). According to Oniki et al. (2018), raising taxation rates will not be effective as long as the number of herder households remains constant. The only way to reduce stocking densities through taxation would be to implement it selectively in certain areas or introduce significant differences in taxation rates (Oniki et al., 2018). In 2021, the Mongolian government reintroduced the livestock head tax again (Unified Legal Information System, 2021). The tax, paid in two instalments each year by herders, goes to the budget of the soum (district) where the livestock is counted and registered (Unified Legal Information System, 2021) but the legal framework does not foresee tax going to the PAs. Besides, there is no capacity for controlling livestock numbers reported by herders and, therefore, taxation is a limited tool for reducing livestock numbers within PAs.

In Mongolia, natural mechanisms for regulating livestock numbers are typically linked to extreme winter events, known as dzuds (Fernández-Giménez et al., 2015). Nowadays, the practice of supplementary winter feeding (Tugjamba et al., 2021a) allows for the survival of large numbers of livestock during harsh winters, potentially leading to overstocking of pastures (Fernández-Giménez et al., 2015; Vetter, 2005). Winter feeding and emergency hay reserves were already common during Soviet times, but livestock numbers were limited (Batdelger et al., 2025). According to the director of the Great Gobi B SPA (Altansukh Nanjid, personal communication, 2025), winter feeding - particularly for cattle - has become more common in the region, and hay production is on the rise. The practice of supplementary feeding, especially during and after droughts, has been a topic of debate in other arid regions such as North Africa and the Middle East (Müller et al., 2015; Vetter, 2005). It is argued that it can decouple the relationship

between vegetation and livestock dynamics, potentially leading to rangeland degradation (Müller et al., 2015; Schulze et al., 2016; Vetter, 2005). Furthermore, the cultivation and storage of forage resources may reduce herder mobility (Tugjamba et al., 2023), which is a fundamental aspect of the pastoral system in these arid areas. If the trend of winter feeding continues in the Great Gobi B SPA, it is likely to lead to overstocking and pasture degradation. Therefore, I recommend discontinuing the practice of winter feeding and limit livestock numbers, and instead exploring alternative mechanisms to support local livelihoods (see sections 4.5.2 and 6.4).

According to the director of the Great Gobi B SPA, herders in the Dzungarian Gobi try to sell large numbers of livestock in autumn when they anticipate an extreme winter, particularly following a dry summer (Altansukh Nanjid, personal communication, 2025). However, this practice is not very common due to lack of slaughterhouses in remote areas (Udval et al., 2024). Still, this approach is similar to practices observed in other parts of Mongolia (Addison & Brown, 2014; Tugjamba et al., 2021b) and in arid Namibia, where herders sell livestock in anticipation of drought-induced losses (Ward et al., 2004). The uncertainty regarding both ecological and economic conditions likely contributes to herders' decisions to hold onto livestock during favourable conditions (Xu et al., 2019) but sell livestock if weather forecasts predict climate extremes (Tugjamba et al., 2021a). There are projects now focusing on slaughtering young animals in autumn instead of having additional pressure on limited winter pastures. However, the consumption of lamb and kid meat have no tradition so far in Mongolia (Munkhzul, 2020).

6.2.3 Livestock production is undergoing socio-economic changes

In remote regions of Mongolia, livestock production often represents the sole income source for households (IPECON / NZNI, 2003), as is the case for approximately 280 herder families with seasonal access to the Great Gobi B SPA. My study found that herder households in this region were entirely dependent on livestock production for their livelihoods, engaging in livestock and livestock product trade and sales. The Great Gobi B SPA's remote location, long distances from urban centres, and harsh climate severely limit alternative income opportunities (IPECON / NZNI, 2003).

Cashmere emerged as the most significant livestock product, aligning with broader trends in Mongolia (Gombodorj, 2021; Joly et al., 2019; Meurs et al., 2017). Mongolia accounts for over 30% of global cashmere production (Morton et al., 2024), making it the country's third-largest export commodity, following copper and gold (Rysbyek & Lei, 2022). Once a luxury item for the elite, cashmere has gained immense popularity in the fast fashion industry, fuelling rising

global demand (Fortune Business Insights, 2025). This boom has led to a dramatic increase in goat numbers, especially in the Gobi, which in turn threatens both rangeland health (Sainnemekh et al., 2022) and biodiversity (Berger et al., 2013), while also exacerbating the vulnerability of pastoral livelihoods (Murphy, 2018).

With cashmere serving as a cash crop, herders are integrated into the market economy, yet their annual incomes are subject to global market fluctuations, making them highly vulnerable to economic instability (Marin, 2019; Murphy, 2018). To address these challenges, several national and international initiatives focus on promoting sustainable cashmere production in Mongolia. These efforts aim at improving cashmere value chains by enhancing market access, securing higher prices for livestock products, and implementing communal pasture management (Addison et al., 2013; Okamoto & Jamsranjav, 2019). Some of these initiatives also include wildlife-friendly pasture management practices (Okamoto & Jamsranjav, 2019). In the Great Gobi B SPA, such efforts are currently supported by the PA management and the non-governmental organisation International Takhi Group (ITG, 2025).

In my study, other livestock products held only minor economic value, with meat and milk primarily being consumed for household needs. Despite this, herder households allocated about one-third of their income to food, followed by expenditures on travel, transport, and clothing based on my study, which collectively accounted for over 60% of household expenses. I concluded that this limited their economic margin and significantly contributed to household vulnerability, particularly when compounded by climatic disasters (Addison & Brown, 2014; Kakinuma et al., 2024). Herders in my study expressed a desire to further increase their herd sizes, a strategy also reported by Addison & Brown (2014), to buffer against extreme climatic events and fluctuations in livestock product prices (Xu et al., 2019).

Another trend I observed in my study was the departure of the younger generation from the herding lifestyle. While children were still seen as valuable assistants during labour-intensive periods, such as the cashmere combing season, this highlights the continued importance of family-centred traditions and social networks in Mongolian herding culture (Fernandez-Gimenez, 1999; Fernández-Giménez et al., 2017). Many herders in my study noted that the available labour limited individual herd sizes to approximately 1,000 small livestock heads.

In recent years, arrangements between absentee herd owners and contracted herders have become more common in Mongolia (Fernandez-Gimenez, 1999; Mijiddorj et al., 2019; Murphy, 2015), though such practices were not yet widespread in my study. In regions such as Eastern and South Africa, similar arrangements have been shown to negatively affect pasture health and

livestock well-being, and are often viewed as socially exploitative (Michler et al., 2019; Moritz et al., 2011).

At the time of my study, livestock grazing had minimal short term impacts on pasture health in the Gobi, and herd sizes remained manageable within the herder families. However, as livestock numbers continue to stay high or rise, herder households in the Great Gobi B SPA may eventually reach herd sizes that are neither ecologically (Sainnemekh et al., 2022) nor socio-economically sustainable, potentially resulting in competition with wildlife populations (Berger et al., 2013). In addition, there is limited knowledge about the grazing impact on pastures in the Altai mountains where herders stay during summer. This poses a threat to the conservation goals of the PA and its buffer zone.

6.2.4 PA management and herders as partners in conservation

The findings of my study indicate that herders generally viewed access to the Great Gobi B SPA positively, although they also encountered challenges related to PA management, particularly with respect to pasture use. Globally, pastures in PAs are often regarded as critical resources for mitigating environmental variability, such as drought in Kenya (Butt, 2011) or extreme winters in Mongolia (Bedunah & Schmidt, 2004; Hess et al., 2010). This, in turn, places additional pressure on endangered or threatened wildlife that rely on PAs as refuges (Kaczensky et al., 2007; Salvatori et al., 2021). Furthermore, access to PAs is often regulated by permissions, which can lead to social conflict within communities when access rights are restricted to specific members, rather than the entire community (Michler et al., 2019). My study highlights the importance of good communication between PA management and pastoral communities, which was regarded as insufficient in my study. I found that herders expressed a strong need for improved communication and collaboration between PA authorities and local communities. These perceptions were contrary to the opinions of the rangers who highlighted a good relationship and communication between themselves and the herding community. The PA rangers emphasized the engagement of community rangers and the participation of local people in other conservation activities such as wildlife counts (Ransom et al., 2012; Vogler et al., 2023).

The results of my pilot study, which aimed to engage herders as citizen scientists in wildlife observations, demonstrated that herders can contribute valuable data to support PA conservation efforts. Due to international initiatives, online citizen science platforms have become more accessible in Mongolia in recent years (Batsaikhan et al., 2023). In particular, platforms such as "Mongolian Biodiversity" now facilitate the collection of data on flora and fauna (Baigali, 2024). I propose the development of a mobile application (app) to be used on smartphones of

herders in the Great Gobi B SPA. This app would allow herders to collect data that could complement wildlife observation data gathered by PA rangers using the SMART app (SMART, 2024), which is submitted to the Mongolian Ministry of Environment and Climate Change.

I conclude that the overall perception of herders regarding the use of natural resources within the Great Gobi B SPA was positive. However, while communication between PA management and the herding community requires improvement, participatory activities offer an effective means of enhancing communication and cooperation and should therefore be actively promoted by PA management.

6.3 Holistic Views Essential for the Integration of Human Land Use in Nature Conservation

6.3.1 Combining ecological and socio-economic data to draw a comprehensive picture

In my research, I employed an integrative data analysis framework, combining quantitative environmental data with both quantitative and qualitative socio-economic information. This approach deemed essential to me, as global rangeland systems are ecologically and socio-economically diverse (Engler et al., 2018). In the past, rangeland systems have been viewed through a narrow lens, illustrated by the ongoing equilibrium versus non-equilibrium debate (Briske et al., 2020; Vetter, 2005). The term “rangelands” is considered narrow by Briske et al. (2025) as it is mainly associated with social systems (Sayre, 2017) that focus on land-use rather than land cover type alone. To enhance the global recognition of the heterogeneous land category, which is often described with different terms such as rangelands, grasslands, or drylands, Briske et al. (2025) recently proposed to find a common category named “grassy biomes”. Typically, rangeland research focused on ecological parameters and grazing regimes (Briske et al., 2011), while social scientists examined herding systems (Fernandez-Gimenez, 2000; Turner, 2009). However, both disciplines have struggled to adequately link ecological, social, economic, and political factors to ecological outcomes and management implications (Sayre et al., 2013). With the growing realization that these social-ecological systems (SES) are complex (Hruska et al., 2017; Vetter, 2005), it has become increasingly evident that integrating social sciences into ecological and biological research is critical (Balmford & Cowling, 2006; Redman et al., 2004). This integration is especially important when research outcomes are intended to inform conservation activities and management practices (Balmford & Cowling, 2006), as is

the case for the Great Gobi B SPA, a IUCN I protected area and a UNESCO Man and Biosphere Reserve. While ecological approaches are often based primarily on quantitative data, qualitative methods in conservation biology are invaluable for understanding human land use and decision-making processes (Sutherland et al., 2018). While my study served as a case study, the discussion on the term of grassy biomes (Briske et al., 2025) shows the need to integrate the knowledge of such local systems that I studied into a much broader context of the SESs which are home to many pastoral communities and cover wide ranges of landscapes worldwide.

I began my fieldwork with interviews of herder households (Figure 6.4). These interviews provided data on household information, livestock status, and economic conditions. They also allowed me to introduce myself and my research, ensuring informed consent (Nijhawan et al., 2013) and establishing a relationship of trust with the local herding community.



Figure 6.4: Different interview sessions with respondents inside the Great Gobi B Strictly Protected Area in Mongolia, in 2019. Picture a) shows a herder household interview with a female herder. In picture b) a group interview with three rangers of the Great Gobi B Strictly Protected Area is shown. Pictures c) and d) show different focus group sessions with herders. (Photos by Lena Michler, 2019)

This was particularly important, as I was fitting GPS collars on goats which allowed me to track goat as well as herder household movements (Figure 6.5). Movement ecology, a growing field, offers valuable insights into various ecological disciplines, including livestock and wildlife

mobility, behaviour, and resource use (Seidel et al., 2018). However, GPS collars can induce stress or health issues in animals (Herlin et al., 2021) or may alter their short-term behaviour (Stabach et al., 2020), plus they indirectly also monitor the herder family. Therefore, it was essential in my work that herders were fully informed and provided consent prior to the study. Further, I integrated the tracking data with remotely sensed environmental and climate data. Remote sensing offers a non-invasive method for collecting data over large spatial and temporal scales (Boyle et al., 2014; Senf, 2022). This technology allows for the identification of changes in land cover at the landscape scale and highlights areas in need of conservation efforts (Boyle et al., 2014). In many cases, combining remotely sensed data with field-based ecological methods is essential for a comprehensive understanding of ecological systems at the landscape scale (Cavender-Bares et al., 2022), as demonstrated in my study through ground-based vegetation and soil assessments (Figure 6.5).

My study did not encompass political or anthropological perspectives, which would have further enriched the understanding of the pastoral system in the Dzungarian Gobi. However, I gained a good overview of the herding system, and I was able to follow-up emerging questions during several focus group interviews (Figure 6.4). In addition, I tested a practical approach for engaging herders as citizen scientists in wildlife observation. This approach has the potential to enhance communication and cooperation between the PA management and the local herding community (McKinley et al., 2017).

The results of my study emphasize the need for a regional, yet holistic, approach to rangeland systems, especially when the goal is to derive management decisions based on research findings.



Figure 6.5: Different field based data sampling methods applied in the Great Gobi B Strictly Protected Area in Mongolia, 2018-2020. Picture a) shows a goat with a GPS collar. In picture b) a goat gets weighed by the main author and a ranger of the protected area. Picture c) shows vegetation cover sampling within a square of 100 m². In picture d) a 1 m² is shown to sample biomass of different plant species. (Photos by Lena Michler, 2019)

6.3.2 Additional challenges of livestock herding in a protected area

My study served as a case study on the integration of human land use in nature conservation. In the Great Gobi B SPA, land-sharing allows herders and their livestock to coexist with wildlife within the limited use zone of the PA. Generally, positive effects of livestock on wildlife are rarely found worldwide (Gordon, 2018; Schieltz & Rubenstein, 2016). However, Fynn et al. (2016) demonstrated that managed livestock grazing in African savannas can enhance structural vegetation heterogeneity and create nutrient hotspot, which reduce competition and benefit wildlife. Neutral interactions between livestock and large herbivores are typically associated with low stocking densities or the use of niche forage resources (Gordon, 2018). In contrast, negative effects of livestock grazing on wildlife are far more common, including disease transmission, particularly around shared water points (Dayaram et al., 2021; Wiethoelter et al., 2015). A tragic, most recent, example of disease transmission at the livestock-wildlife interface occurred during the 2016-2017 outbreak of peste des petits ruminants virus (PPRV) in Mongolia, which led to mass mortality among the critically endangered Mongolian saiga antelope

(*Saiga tatarica mongolica*; Kock, 2019). Although the outbreak was followed by a vaccination campaign for domestic goats and sheep, the highly contagious virus spread to thousands of Mongolian saiga antelopes, and also affected Siberian ibex (*Capra sibirica*) and goitered gazelle (*Gazella subgutturosa*, Kock, 2019; Shatar et al., 2017).

Furthermore, competition for forage and water resources between livestock and wildlife, increased predation, and habitat fragmentation due to fencing (Barroso & Gortázar, 2024; Gordon, 2018; Xu et al., 2020) have commonly been observed worldwide (Otuoma et al., 2009; Xu et al., 2020). The results of my pilot wildlife diary study indicated that herders and their livestock frequently encounter wildlife (Chapter 5), which could potentially affect wildlife species. To explore this further, I examined the spatial overlap of Przewalski's horses and livestock over a one-year period in the Great Gobi B SPA (Michler et al., 2021). In this study, I combined GPS tracking data of small livestock herds with weekly location data of Przewalski's horse groups, collected by PA rangers. The result showed that the ranges of Przewalski's horses and livestock overlapped primarily around permanent and ephemeral water points (Figure 6.6), similar to the findings by Mischke (2023), based on my data. However, the resources around water points were utilized in different seasons. In Kenya's Southern Rift Valley, wildlife and livestock share the same water points but use them at different times of the day (Connolly et al., 2021). According to Kaczensky et al. (2017), Przewalski's horses and Asiatic wild asses in the Great Gobi B SPA tend to move into suboptimal shrub habitats during winter months, when herder camps are usually situated in grass-dominated areas. This shift may also lead to changes in the diet of wild equids, with a greater reliance on browsing (Šturm et al., 2017).

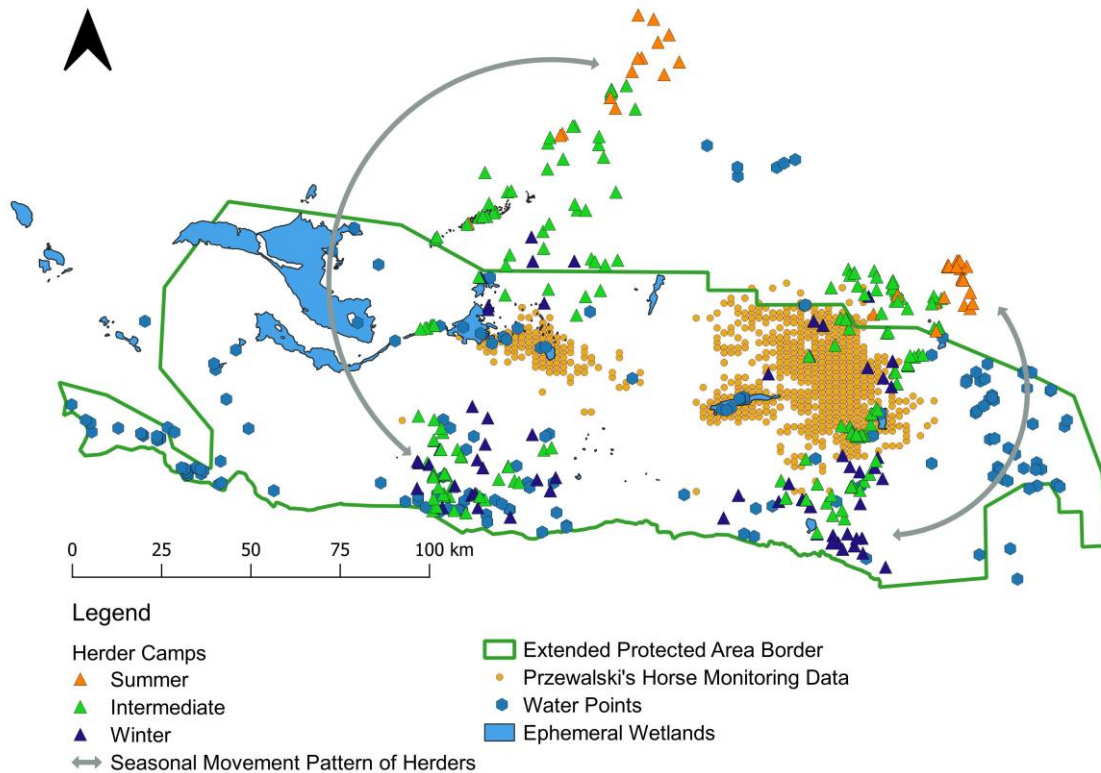


Figure 6.6: Map of the Great Gobi B Strictly Protected Area in Mongolia showing seasonal herder camps (triangles). Grey arrows illustrate the seasonal movements between summer camps in the North and winter camps in the South. The green line shows the protected area border. Yellow dots visualize grid-based Przewalski's horse monitoring data in the years 2018 and 2019 recorded on a weekly basis. Water points and ephemeral wetlands are shown in light blue. Adapted from Michler et al. (2021)

Given the spatial and pasture-use overlap between small livestock herds and Przewalski's horses, further research is necessary to assess the extent of competition for resources between wildlife and livestock in the Great Gobi B SPA, even if resources are used in different seasons. To address this, I investigated potential forage overlaps between livestock species (goats, sheep, cattle, domestic horses, and camels) and three wild herbivores: the Przewalski's horse, Asiatic wild ass and goitered gazelle.

I collected dung samples from both wild and domestic herbivores to identify forage overlaps using DNA-bar coding (Figure 6.7), following a method similar to that of Sugimoto et al. (2018). In the initial trial, samples were dried in paper bags in the sun. In the second trial, dung was stored in plastic tubes containing silicate beads. Unfortunately, both preservation methods led to mold growth, rendering the samples unsuitable for DNA-barcoding analysis.

Sugimoto et al. (2018) observed high dietary diversity in goats and sheep, along with notable dietary overlap with Mongolian gazelles and Asiatic wild asses. In light of increasing livestock

numbers, these findings suggest a growing risk for forage competition between domestic and wild ungulates in Mongolia's desert steppes (Sugimoto et al., 2018). This underscores the need for further research in the Great Gobi B SPA, using improved and adapted sampling and preservation techniques.



Figure 6.7: Sampling of camel (left side) and cow (right side) dung for DNA-barcoding in the Great Gobi B Strictly Protected Area in Mongolia. (Photos by Lena Michler, 2019)

My results indicated that forage quality and quantity were the most important determinants for herders to select grazing areas. For small livestock, total forage intake has a greater influence on weight gain than forage digestibility alone (Glindemann, 2007; Lippke, 2002). Therefore, the availability of nutrient-rich vegetation, which supports weight gain, was a key factor in herders' decisions when choosing autumn camp locations in my study, similar to patterns observed in other regions of Mongolia (Behnke et al., 2011).

My study further revealed that forage digestibility on pastures decreases as the growing season progresses, a trend also observed in the Inner Mongolian steppe (Glindemann et al., 2009; Hao et al., 2013). I tested a method to establish a proxy for actual forage intake, to better estimate forage intake by livestock in the Great Gobi B SPA. Forage intake can be calculated by measuring livestock faecal output and subtracting the indigestible fraction of forage (Mayes & Dove, 2000).

Hence, I equipped 20 adult goats and sheep from five herds (two individuals per species per herd) with faecal collection bags in autumn 2019 (Pfister, 1985; Tsevegemed et al., 2019). These faecal collection bags were attached with a harness to the animals to collect dung over a 24-hours period over three consecutive days (Figure 6.8). Dry matter content of the faeces was measured after weighing the samples before and after air drying. While the method showed promise, Mayes & Dove (2000) raised concerns about the potential for uncontrollable faecal losses, which can lead to inaccurate estimates, an issue I also encountered. Based on this, I

recommend the use of inert markers as a more reliable method for estimating faecal output (Coleman, 2005; Glindemann, 2007).

Additionally, determining forage digestibility presents challenges, as average plant biomass samples from heterogenous pasture may not accurately reflect the actual forage consumed by livestock (Glindemann, 2007). These parameters are essential to determine appropriate stocking densities and ensuring sustainable rangeland management (Ren et al., 2021). Therefore, further research is needed to quantify forage intake more precisely by livestock in the Dzungarian Gobi.



Figure 6.8: Faecal collection bag method: Right side shows how the faecal collection bag strapped got strapped with a harness on the goat. Left side shows how the faeces were collected in the evening. (Photos by Lena Michler, 2019)

One of the key findings of my study was the limited evidence for grazing gradients around herder camps. However, since vegetation sampling was conducted over only three seasons, I was unable to provide any long-term results. Notably, even within the short study period in my study, the variability of precipitation between two years already resulted in significant differences of plant biomass production. In addition, livestock numbers have increased in recent years, but the effects of grazing take time to become visible - especially given the high variability in weather and the impacts of dzud events in Mongolia (Sainnemekh et al., 2022; Vova et al., 2020). This highlights the importance of long-term vegetation monitoring, particularly in arid ecosystems where multi-year vegetation assessments are essential to identify ecological processes driving vegetation change (Hanafi & Jauffret, 2008; Wiegand & Jeltsch, 2000), many of which are often reflected in local soil seed banks (van Langevelde et al., 2016). For example, the plant species *Stipa* spp., identified in my study as key forage resource for livestock in the Great Gobi B SPA, rarely germinates in the field except under extremely moist conditions (Ronnenberg et al., 2008). As such, understanding the seed bank potential in soils is critical for

both grazing management and conservation (Ma et al., 2010).

Soil seed banks act as natural reservoirs of plant species and can provide insights into the long-term resilience of grazed ecosystems (Ma et al., 2019). Hence, I conducted a soil seed bank analysis in addition to above-ground vegetation assessments (Chapter 2). In 2018, I collected 270 soil samples from 30 herder camps and placed them in pots inside a greenhouse, where they were regularly watered over a 60-day period to monitor germination (Figure 6.9). Surprisingly, no seedlings emerged during this period. Further analysis of ten samples, conducted by sieving under laboratory conditions at the Mongolian University of Life Sciences in Ulaanbaatar, also yielded no detectable seeds.



Figure 6.9: Greenhouse set-up for seed bank germination experiment in the Great Gobi B Strictly Protected Area in Mongolia 2018. (Photos by Lena Michler, 2018)

The absence of germination in my seed bank experiment may be attributed to the high interannual variability in precipitation typical of the Central Asian steppe, which results in irregular and often limited seed production (Wesche et al., 2006). Additionally, while seed dormancy, i.e., the delay of germination (Baskin & Baskin, 2004), is a common strategy for seeds in cold deserts of North America, it is less prevalent in the steppe and desert vegetation of Mongolia (Wesche et al., 2006). In these ecosystems, many perennial species germinate directly when summer temperatures are favourable (Ronnberg et al., 2007) and sufficient moisture from rainfall is available (Wesche et al., 2006).

Sexual reproduction via seeds is generally rare in the Gobi Altai region (Wesche et al., 2005). Similarly, *Stipa gobica* is known to only re-seed every seven to ten years (Lavrenko & Karamysheva, 1993), and regeneration cycles of Gobi desert woody plants such as *Haloxylon ammodendron* and *Iljinia regelii* may span up to 50 years (Gunin et al., 2003). Most grass species in Asian drylands are long-lived and tend to reproduce vegetatively, particularly under unfavourable climatic conditions (Wesche et al., 2005). As many perennial species do not rely

heavily on seed production or seed banks for reproduction (Wesche et al., 2006), this may explain the complete absence of viable seeds in the soil samples I collected. In dryland ecosystems, facilitation - where plants improve the ecological conditions of other plant species (Danet et al., 2021), for example by enhancing shading and water infiltration (Synodinos et al., 2015) - contributes to the formation of vegetation patches (D’Odorico et al., 2006). Consequently, future studies should consider focusing seed bank sampling near or under shrubs.

Nevertheless, the lack of any detectable seed bank in my study underscores the importance of long-term assessments to better understand the resilience of these ecosystems, especially under increasing grazing pressure. Herbivore browsing can suppress plant flowering and thereby reduce seed production (Wesche et al., 2010). Species like *Haloxylon ammodendron*, an important forage resource for livestock and wildlife, especially in winter (Kazantseva et al., 2012; Šturm et al., 2018) require further investigation in the context of grazing impacts in the Great Gobi B SPA.

To better understand the environmental parameters influencing vegetation distribution in the Dzungarian Gobi, I analysed the soil types associated with different plant communities (von Wehrden et al., 2006) on grazing sites and around water points in the Great Gobi B SPA (Figure 6.10 and 6.11). Given that herders demonstrate clear preferences for specific plant communities when selecting their camp locations, I recommend to further investigate the effects of varying grazing intensities on soil nutrient dynamics (Sasaki et al., 2008).

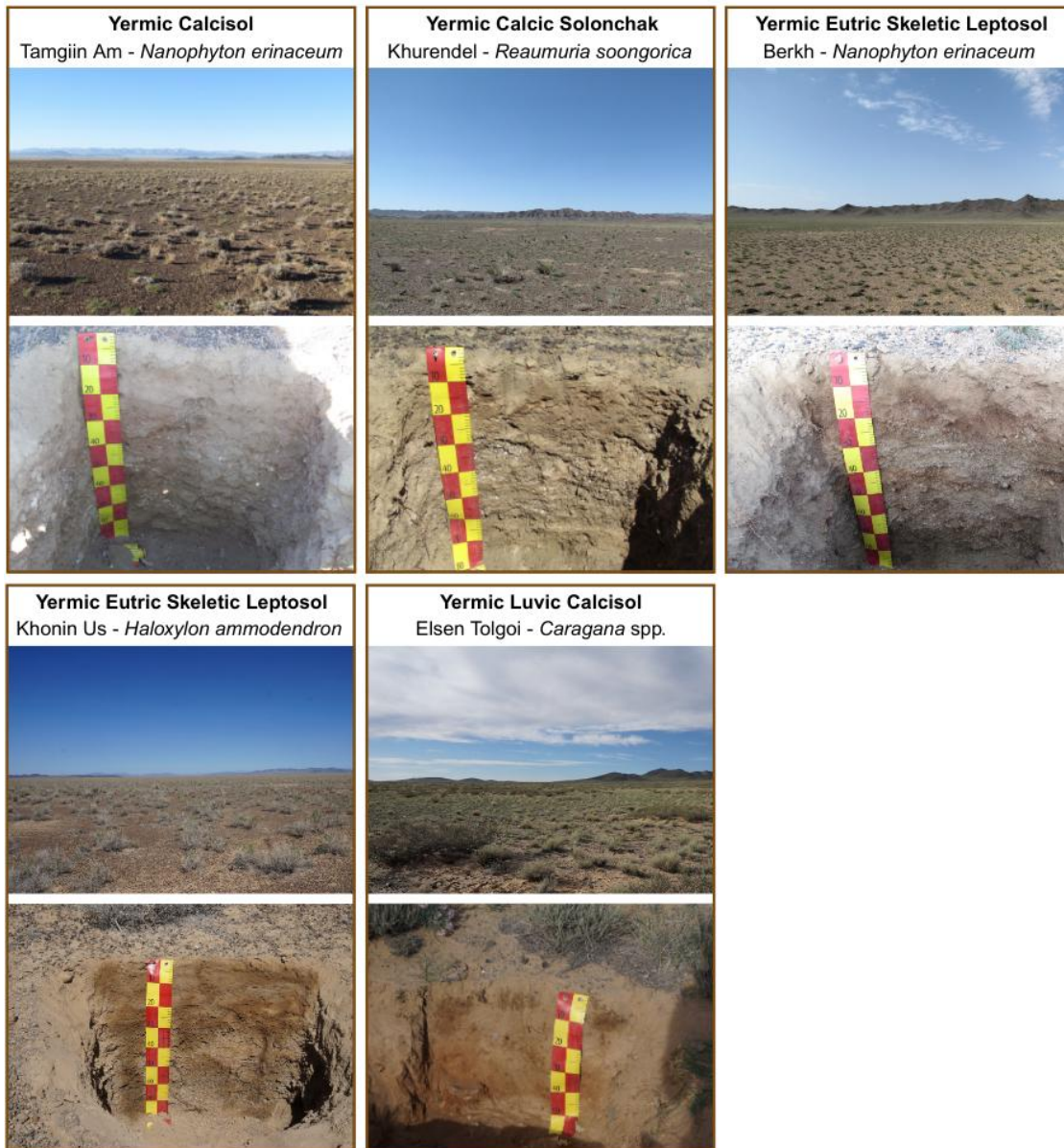


Figure 6.10: Soil profiles in different plant communities located in commonly used grazing areas by herders, their livestock, and wildlife in the Great Gobi B Strictly Protected Area in Mongolia. (Photos by Lena Michler, 2018 and 2019)

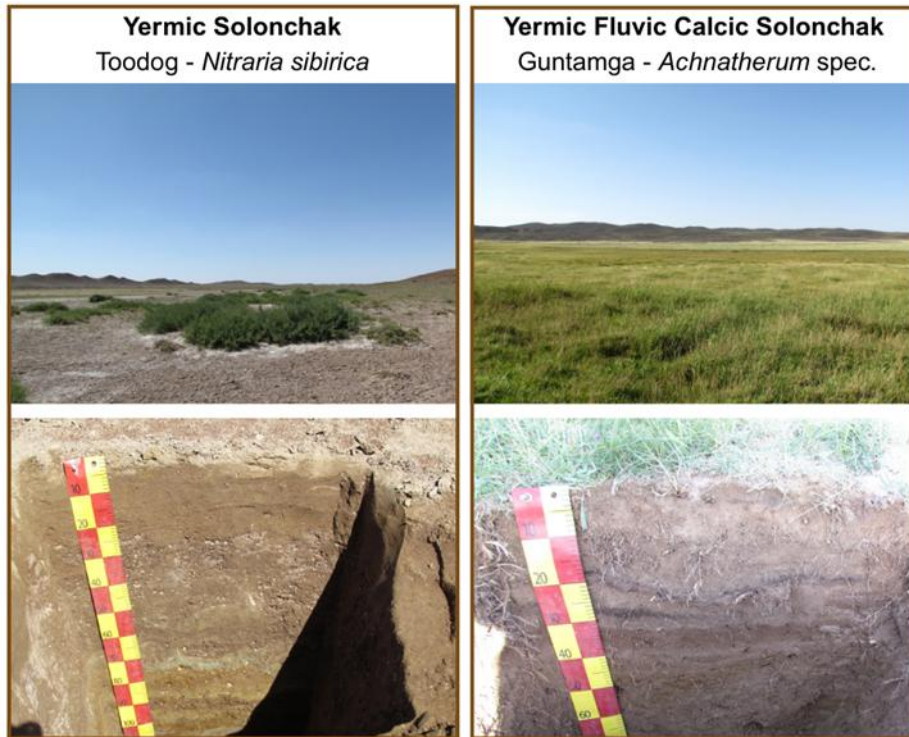


Figure 6.11: Soil profiles in different plant communities located around water points used by herders, their livestock, and wildlife in the Great Gobi B Strictly Protected Area in Mongolia. (Photos by Lena Michler, 2018 and 2019)

Grasslands around the world are widely recognized as important carbon sinks in the context of climate change mitigation (Chang et al., 2021). Given that grazing intensity alters carbon storage capacity of rangelands (He et al., 2011), I aimed to examine the carbon storage potential across different plant communities in the Great Gobi B SPA (Michler et al. in preparation).

Globally, climate change will continue to impact arid rangelands and their ability to provide essential ecosystem services (Briske, 2017). In the Dzungarian Gobi, the interannual variability of precipitation is projected to increase, with a further decline in summer rainfall in the coming decades (Mischke, 2023). My findings also indicate the emergence of atypical autumn rainfall events (Figure 2.2), emphasizing the need for continued study of climate change effects in this region. These environmental shifts must be considered in PA management decisions. However, ecological considerations alone are not sufficient, social, economic, and political dimensions must also be integrated, especially when policy changes affect pastoral mobility and livelihoods.

Overall, land tenure changes and landscape fragmentation by altered land rights affect pastoral mobility patterns, weakening social networks that support them (Galvin, 2008). Socio-

economic changes further alter pastoral mobility, which accounts for the cornerstone for both ecological resilience and socio-economic sustainability. In Mongolia, the biggest change is the switch from subsistence livestock husbandry to a market economy, resulting in changes of herd sizes and composition (Meurs et al., 2017; Tumur et al., 2020). In combination with climate change, pastoral communities will be forced to adapt to immense challenges in the coming decades. Therefore, any PA management strategy or decision by policy makers affecting pastoral communities must be carefully considered to ensure long-term sustainability of both ecosystems and local livelihoods.

6.4 Recommendations and Conclusion

My study highlights the ecological and social complexities of livestock grazing and pastoral livelihoods on the rangelands in the Dzungarian Gobi. The primary objectives of my research were to investigate mobility patterns of nomadic herders, the effects of grazing on Gobi pastures, the socio-economic challenges faced by herder households, and the interactions between local herders and the management of the Great Gobi B SPA. My study results can now provide a basis for improved management of pastures and policy decisions in areas used by wildlife and livestock alike.

Contrary to the global trend of declining pastoral mobility (Adriansen, 2008; Liao et al., 2020), herders in the Dzungarian Gobi remain highly mobile, adapting through large-scale movements, high flexibility, and altitudinal migration to cope with the immense variability in natural resources. However, I observed several trends in this study that may jeopardize these pastoral adaption strategies: (1) The desire to increase livestock numbers for meeting economic needs, to an extent that likely is unmanageable for individual herder households and threatens rangeland health and biodiversity. (2) The focus on a single cash crop - cashmere - narrowing herder households' economic margin and potentially leading to overstocking and overuse of pasture resources. (3) The trend of the younger generation leaving the herding lifestyle, leading to the disruption of the traditional family-centred lifestyle. Most of these trends I detected in my study are also evident in many other pastoral systems worldwide. In Inner Mongolia, excessive livestock numbers have led to rangeland degradation (Briske et al., 2015) and all over Africa, livestock numbers now dominate the herbivore biomass and have led to significant wildlife declines (Hempson et al., 2017; Ogutu et al., 2016). In Kenya, pastoral communities depend to a vast extent on camel milk for their diet and household income (Elhadi et al., 2015). From Africa, the Middle East, to southern and eastern Asia, herding has become unpopular in the younger

generation (Schlecht et al., 2020), who nowadays has different lifestyle preferences (Ning et al., 2025). These trends have global implications but are linked to local and regional developments, as I show in my case study, which highlights the need for adapted management and policy strategies.

Based on findings of my study, I propose the following recommendations to researchers, policymakers and PA managers of the Great Gobi B SPA to support sustainable pasture management in line with conservation goals, and strengthen pastoral resilience:

1) Maintain and Encourage Pastoral Mobility

The results of my study clearly demonstrate that mobility, flexibility, and altitudinal migration are essential adaptation strategies that enable herders to manage the high variability in spatial and temporal forage resource availability. Land use policies within and around the Great Gobi B SPA should promote flexible, spatially, and temporally adaptive pasture use, allowing for mobility in response to fluctuating ecological conditions, not only during climate emergencies. According to Batdelger et al., (2025) practicing mobility is often difficult for herders in Mongolia due to poorly functioning institutional systems.

I recommend implementing participatory pasture management within the limited-use zone of the Great Gobi B SPA and its buffer zone to minimize ecological impacts and align livestock grazing with conservation objectives. A good practice example is the country-wide “resilience-based management system” which has been established in Mongolia (Dashbal et al., 2023). Within this programme, herders are actively involved in pasture monitoring methods. The collected data are discussed annually with herders and government staff to adapt pasture management plans (Dashbal et al., 2023). I recommend including herders in rangeland management activities within the Great Gobi B SPA and focus on regulating grazing intensity and stocking densities at winter camps, as these areas are critical resource bottlenecks in this system. Additionally, summer pastures in the Altai mountains, outside of the Great Gobi B SPA, should also be included in monitoring assessments to fully capture the seasonal migration patterns of herders and their livestock.

2) Control and Limit Livestock Numbers

Given the growing trend of rising livestock numbers in Mongolia (Mongolian Statistical Information Service, 2025), also reported in my study for the Great Gobi B SPA, I advise controlling and limiting livestock populations within the PA. However, I strongly caution against applying

the concept of carrying capacity in this arid system, as it fails to account for spatial and temporal heterogeneity of resource (Briske et al., 2020). Instead, I recommend adopting more flexible stocking densities based on seasonal resource availability and ecological conditions within each year, rather than fixed livestock numbers. Flexible stocking densities in semi-arid rangelands in Northern Australia have been shown to be ecologically more sustainable and improved livestock productivity (Pahl et al., 2016). Through ongoing vegetation, livestock and wildlife monitoring, an adaptive approach can be developed that reflects actual changes and dynamics in environmental and socio-economic conditions. Defining appropriate stocking densities should not only consider ecological factors but also recognize the socio-economic needs of pastoral communities. As discussed in Chapter 4, government intervention is necessary to effectively reduce livestock numbers. Policymakers should engage in participatory discussions, incorporating input from PA managers, local herders, and rangeland experts, and apply adaptive strategies based on real-time monitoring data.

3) Establish Long-Term Ecological Monitoring

Long-term ecological monitoring is essential for detecting shifts in plant species or alterations in plant and soil nutrient content. Therefore, I recommend establishing long-term vegetation plots in the Dzungarian Gobi to assess annual and interannual variability in plant biomass, vegetation cover, and plant species composition under fluctuating precipitation and different grazing pressures. Additionally, the role of soil seeds banks in arid systems requires further investigation through refined sampling and analysis techniques, focused on multiple year studies to understand the long-term resilience of the ecosystem. Similar long-term monitoring assessments have been done on pastures in Inner Mongolia (Li et al., 2015), in Kyrgyzstan (Zhumanova et al., 2021), and in Kenya (Western et al., 2021).

Climate data should also be integrated into vegetation assessments to understand the impact of precipitation variability on forage availability under climate change. I further recommend incorporating traditional ecological knowledge (TEK) and citizen science data, collected by herders, into ecological monitoring systems utilized by PA rangers and researchers. Herders in the Dzungarian Gobi practice a vast TEK with deep knowledge, encompassing detailed understanding of seasonal pasture suitability, optimal timing and routes for herd movements, and the spatial-temporal distribution of nutrient-rich forage for their livestock. The application of this TEK of Mongolian herders did not change much in the last decades although Mongolia was undergoing several political and socio-economic changes and plays an integral part to the development of locally adaptive solutions (Batdelger et al., 2025). In Mexico, for example, TEK is

integrated in the management of edible wild plant species in a Biosphere Reserve (Pío-León et al., 2017). A data platform that facilitates the exchange of information between PA management, researchers, and local communities would help integrate both local and scientific knowledge. Similar approaches are facilitated through platforms such as CONECT-e (2025) focusing on the exchange of TEK.

4) Support the Socio-Economic and Ecological Resilience of Herder Households

To alleviate the economic pressures on herder households that drive them to increase livestock numbers, it is essential to enhance the herder's economic resilience by improving access to reliable markets and social services such as healthcare and education. Additionally, promoting alternative income sources can reduce dependency on cashmere and enhance income diversification. Government and non-government initiatives should focus on creating markets for other livestock products, such as camel and sheep wool, meat, or promoting the sale of dairy products during summer months. These recommendations are supported by other reports and studies in Mongolia (Morton et al., 2024; Spiess et al., 2023; Tumur et al., 2020).

Well-managed PAs can create job opportunities in conservation or through eco-tourism (Goodwin & Roe, 2001) as, for example, in the Annapurna Conservation Area in Nepal (Nepal et al., 2021) or in the Makuleke contractual Park Community Project in South Africa (Matiku et al., 2020). However, this will likely benefit only a small number of households (Nepal, 1997; Nepal et al., 2021). To further diversify livelihoods, training programs for herders on alternative incomes opportunities should be implemented by government or non-government institutions. Therefore, I recommend fostering participatory rangeland management approaches to enhance both the socio-economic and ecological resilience of herder households in the Great Gobi B SPA. Through herder cooperatives, market access and bargaining power can be enhanced, and sustainable grazing management can be promoted. Herder cooperatives can play a vital role in replacing traditional family-centered practices, which are being influenced by recent trends in urbanization. Furthermore, through herder cooperatives, equitable value chains can be created, ensuring fair prices for livestock products and greater financial benefits for herders. PA management can support local initiatives by encouraging wildlife-friendly and sustainable livestock production. This approach would contribute to sustainable pasture use and would improve marketing opportunities for livestock products. Good practice examples of such efforts are already existing by several national and international initiatives in Mongolia (Addison et al., 2013; Okamoto & Jamsranjav, 2019).

5) Foster Community Engagement in Conservation

I see great potential in expanding the involvement of local herding communities in conservation activities within and around the Great Gobi B SPA. Not only will this increase conservation awareness within the communities, but it will also improve the outcomes of conservation activities by integrating local knowledge and fostering active participation.

I recommend enhancing communication between PA management and local communities by implementing regular meetings and events. Further, community-based monitoring programs should be established to actively involve local herders in the collection of wildlife and environmental data. Developing an app for herders to collect wildlife and environmental data could streamline this process. Internationally platforms such as iNaturalist (2024) and domestic solutions like “Mongolian Biodiversity” (Baigali, 2024) offer the opportunity to share biodiversity data. In addition, apps like SMART (2024) and BIOSAN (WWF, 2023) are already used in Mongolia for biodiversity monitoring.

My study has contributed to a deeper understanding of adaptation strategies to ecological and socio-economic changes among Mongolian livestock herders. Large-scale mobility remains a key practice in this arid rangeland system, that currently shows only limited evidence for pasture degradation. However, I point out that effective pasture management is critical for sustainability, given the socio-economic pressures on herder households to increase livestock numbers, combined with the impacts of climate change. Regular monitoring and controlling mechanisms for livestock populations are essential to prevent an overexploitation of pasture resources, which would jeopardize both biodiversity conservation and herders’ livelihoods. I conclude that long-term environmental assessments within and around the Great Gobi B SPA are necessary to detect changes in pasture ecosystems. While the Great Gobi B SPA management is not directly responsible for maintaining or improving local livelihoods, it can greatly contribute to enhancing the understanding of conservation goals through participatory activities. Nevertheless, it remains a national task to support herding communities by ensuring mobility, access to markets and social services, and opportunities for economic diversification, thereby strengthening their ecological and economic resilience.

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Appendices

Appendix A

Table A1: Summary of GPS tracking data acquired from 19 livestock herds in the Great Gobi B, Mongolia, during the monitoring period between August 2018 and May 2020.

Herder ID	Start	End	Duration (days)	Observations
1a_East	22.08.2018	02.05.2020	620	19211
1b_West	23.08.2018	18.06.2019	299	9246
2a_East	30.10.2018	29.04.2020	548	16976
2b_West	23.08.2018	27.04.2020	547	16964
3a_East	13.11.2018	29.04.2020	534	16548
3b_West	23.08.2018	03.05.2020	618	19163
4a_East	21.08.2018	28.04.2020	595	18430
4b_West	23.08.2018	09.11.2019	420	13409
5a_East	22.08.2018	29.04.2020	617	19104
5b_West	23.08.2018	29.04.2020	445	13778
6a_East	22.08.2018	29.04.2020	616	19117
6b_West	23.08.2018	09.07.2019	288	8993
7a_East	22.08.2018	01.05.2020	502	16006
7b_West	23.08.2018	02.05.2020	444	13752
8a_East	22.08.2018	02.05.2020	620	19191
8b_West	23.08.2018	01.05.2020	618	19153
9a_East	22.08.2018	01.05.2020	619	19184
10a_East	22.08.2018	02.05.2020	620	19211
12a_East	22.08.2018	27.04.2020	544	16839

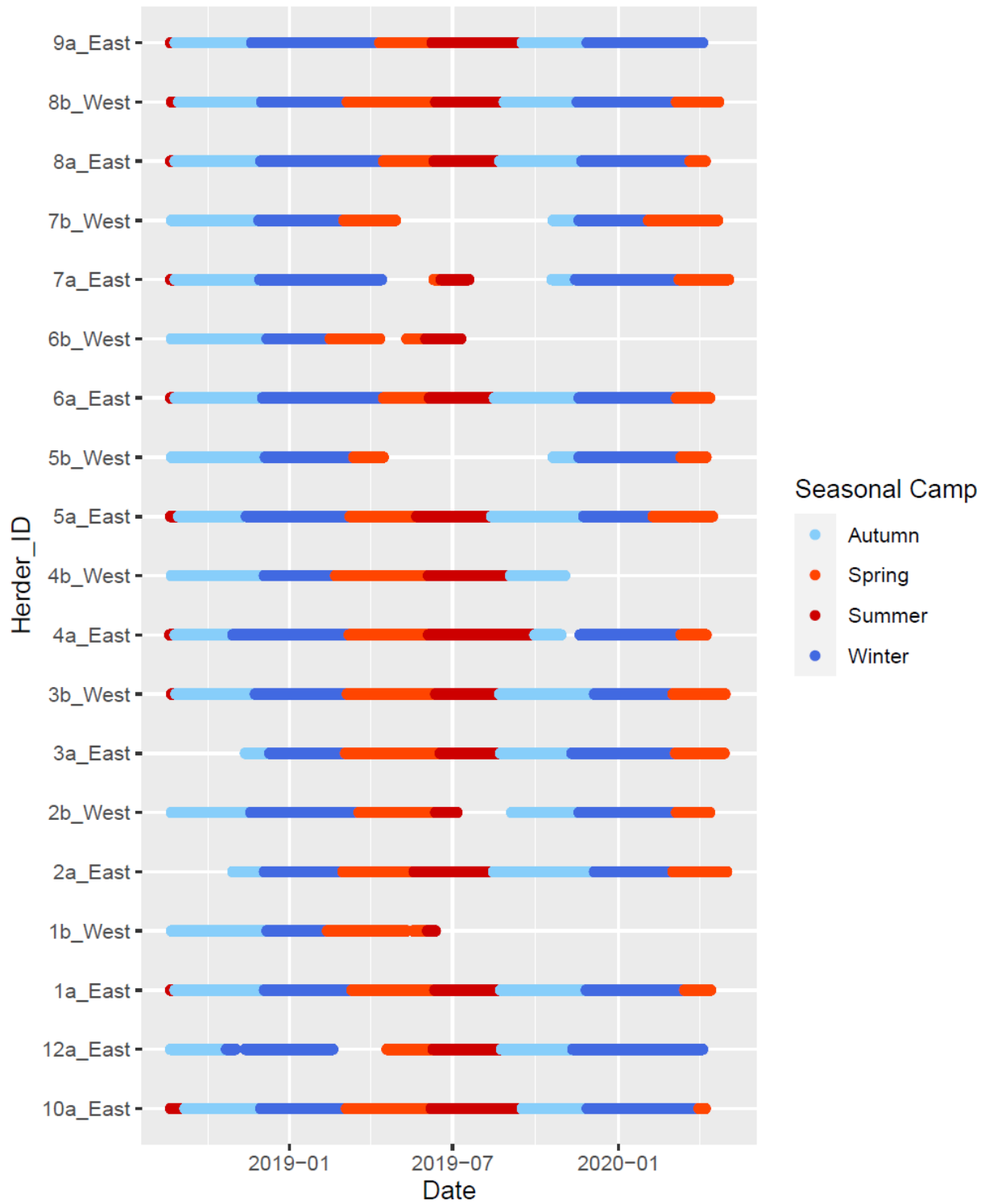


Figure A1: GPS monitoring period of 19 livestock herds between August 2018 and May 2020

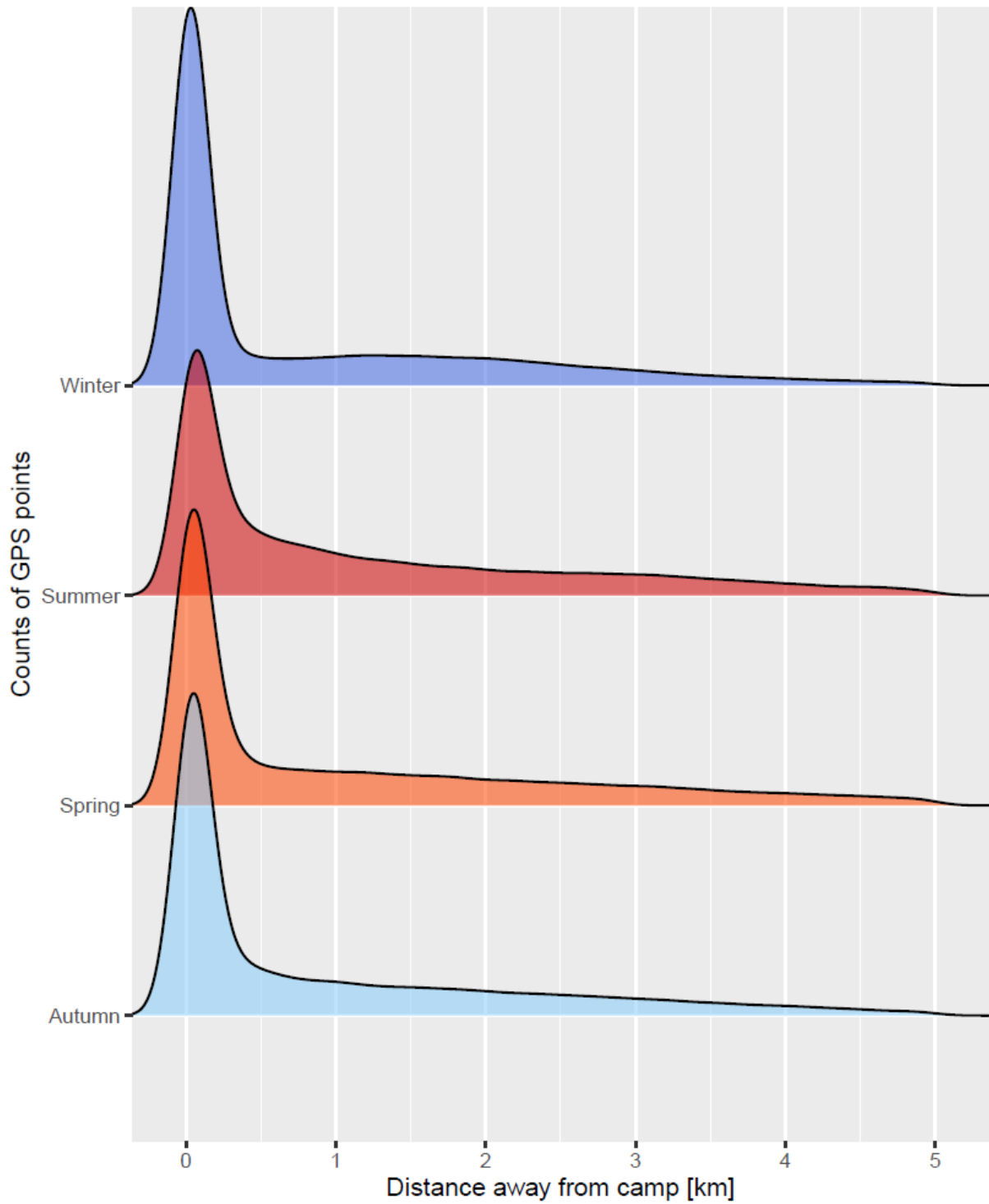


Figure A2: Density ridgeplot shows densities of GPS tracking observation counts along the distance away from camp sites in four different seasons (Winter: $N = 114673$; Summer: $N = 38614$; Spring: $N = 71480$; Autumn: $N = 86020$) in the Great Gobi B SPA, Mongolia.

```

1 // Package for exporting an image collection
2 var batch = require('users/fitoprincipe/geetools:batch');
3 //Load protected area boundary
4 var GGB=GGB_2010.geometry();
5 var aoi=GGB_2010;
6 Map.addLayer(GGB_2010);
7 //MODIS images only of the summer months (May until September) clipped to my area of interest
8 var evi = ee.ImageCollection('MODIS/006/MOD13Q1') //atmospherically corrected surface reflectance from the Landsat 8 OLI/TIRS sensors
9   .filterDate('2000-05-01', '2020-09-30') //select time period
10  .filter(ee.Filter.dayOfYear(122, 275)) //days of the year to select only summer images from 1st of May until 30th of September
11  .select('EVI')
12  .map(function(image){return image.clip(GGB_2010)});
13 print(evi, 'evi');
14 print(evi.size());
15 //Select palette for evi (enhanced vegetation index)
16 var eviVis = {bands: ['EVI'], min:0.0, max: 8000, palette: ['FFFFFF', 'CE7E45', 'DF923D', 'F1B555', 'FCD163', '99B718',
17   '74A901', '66A000', '529400', '3E8601', '207401', '056201',
18   '004C00', '023801', '012E01', '011D01', '011301'], };
19 // EVI statistics (mean and standard deviation)
20 var EVIMean = evi.mean();
21 var EVISd =evi.reduce(ee.Reducer.stdDev());
22 //add mean EVI to the map
23 Map.addLayer(evi.mean(), eviVis, 'EVI_Mean', 0);
24 //Calculate the mean evi of the image of the region over 20 years
25 var MEAN = ee.Number(EVIMean.reduceRegion({
26   reducer: ee.Reducer.mean(),
27   geometry: aoi,
28   bestEffort: true,
29   scale: 1000,
30   maxPixels: 99999999,
31   crs:'epsg:32646',
32   }).values().get(0));
33 print(MEAN);
34 //Define a chart with mean EVI
35 print(ui.Chart.image.series({
36   imageCollection: evi.select("EVI"),
37   region: aoi,
38   reducer: ee.Reducer.mean(),
39   scale: 250 // modis resolution is 250
40 }).setOptions({
41   title:'Mean EVI over 20 years',
42   hAxis:{title:'Year'},
43   vAxis:{title:'EVI'},
44 }));
45 // Export as a single image
46 Export.image.toDrive({
47   image:evi.mean(),
48   description: 'EVI_Mean_20years',
49   region: aoi,
50   scale: 250});

```

Figure A3: Script for EVI processing in the Great Gobi B SPA, Mongolia, covered by Terra Moderate Resolution Imaging Spectroradiometer (MODIS) layers in the Google Earth Engine code editor.

Appendix B

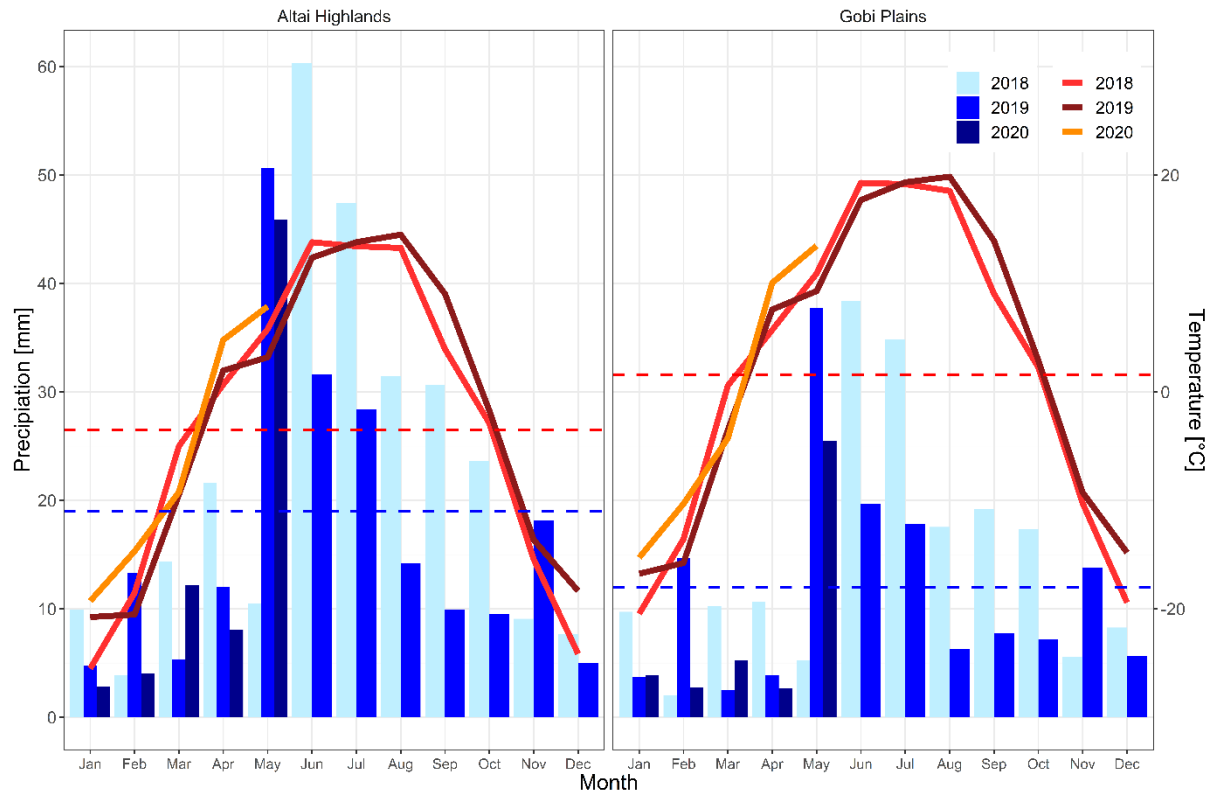


Figure B1: Average monthly temperature and precipitation from January 2018 until May 2020 at herder camps in the Altai highlands and the Gobi plains of Mongolia collected by Copernicus ERA5 monthly data. The dashed lines show the mean precipitation (blue) and mean temperature (red) over the entire study period.

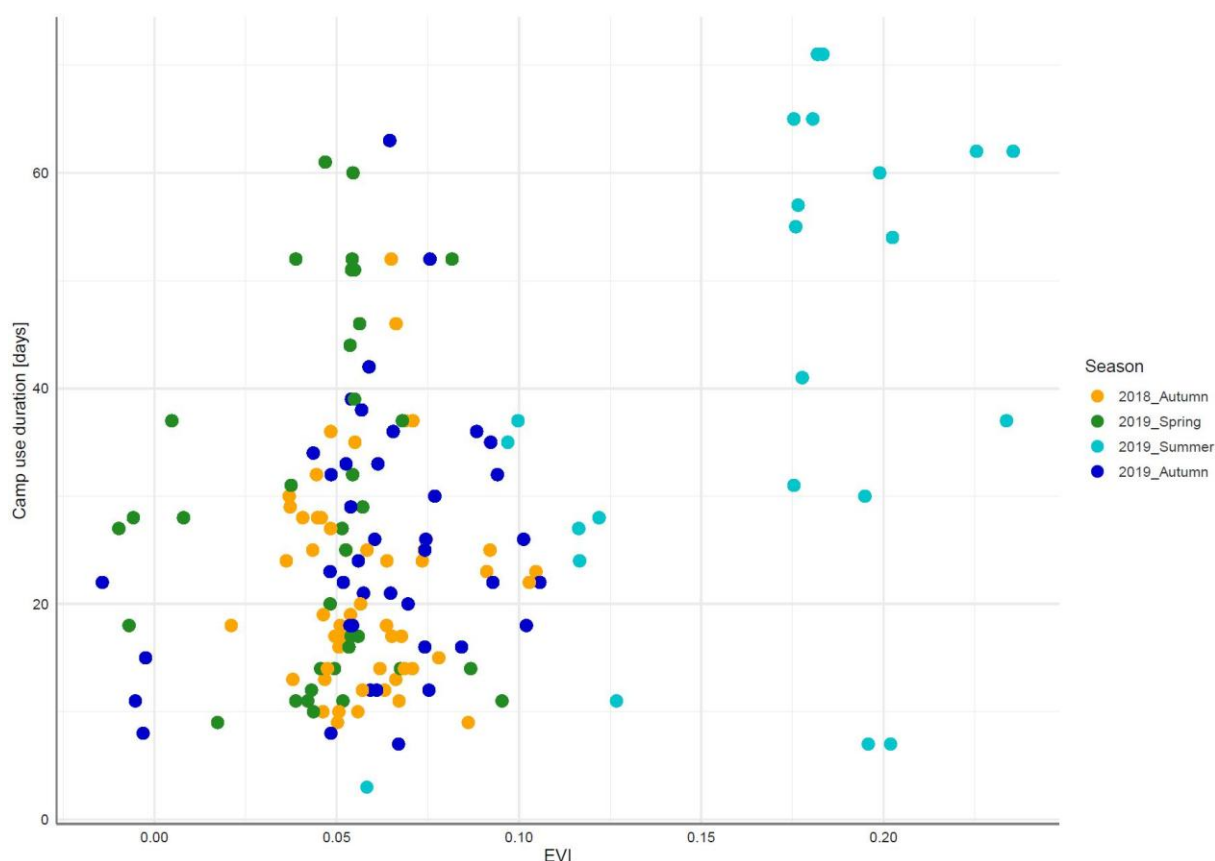


Figure B2: Herder camp use duration (days) dependent on enhanced vegetation index (EVI) and season by year (SeasonalCamp). Herder camps were located in and around the Great Gobi B Strictly Protected Area, Mongolia.

Table B1: All candidate models that we used to estimate the camp use duration (CampUse) in the Great Gobi B Strictly Protected Area, Mongolia, based on GPS movement data collected in autumn 2018, spring 2019, summer 2019 and autumn 2019. The explanatory variables in the model were: enhanced vegetation index (EVI), season by year (SeasonalCamp), herd size (HerdSize) and herd ratio (HerdRatio; goats/sheep) in sheep forage units. Herder ID was included as random effect in all models.

Model	AIC _c	ΔAIC _c	AIC _c weight	Log- Likelihood
EVI + SeasonalCamp + EVI:SeasonalCamp*	32169	0.00	1	-16075
EVI + SeasonalCamp + (1 HerderID)	32385	216	0	-16186
SeasonalCamp + HerdSize + SeasonalCamp : HerdSize	32622	453	0	-16301
SeasonalCamp + HerdRatio + SeasonalCamp : HerdRatio	32673	504	0	-16326
SeasonalCamp	32675	506	0	-16332
SeasonalCamp + HerdSize	32676	507	0	-16331
SeasonalCamp + HerdRatio	32677	507	0	-16331
EVI + HerdSize + EVI:HerdSize	32945	776	0	-16467
EVI	32955	785	0	-16473
EVI + HerdRatio + EVI:HerdRatio	32956	787	0	-16472
EVI + HerdRatio	32956	787	0	-16473
EVI + HerdSize	32957	787	0	-16473
HerdRatio	34051	1881	0	-17021
HerdSize	34052	1882	0	-17022

*The division sign (:) represents an interaction between two explanatory variables

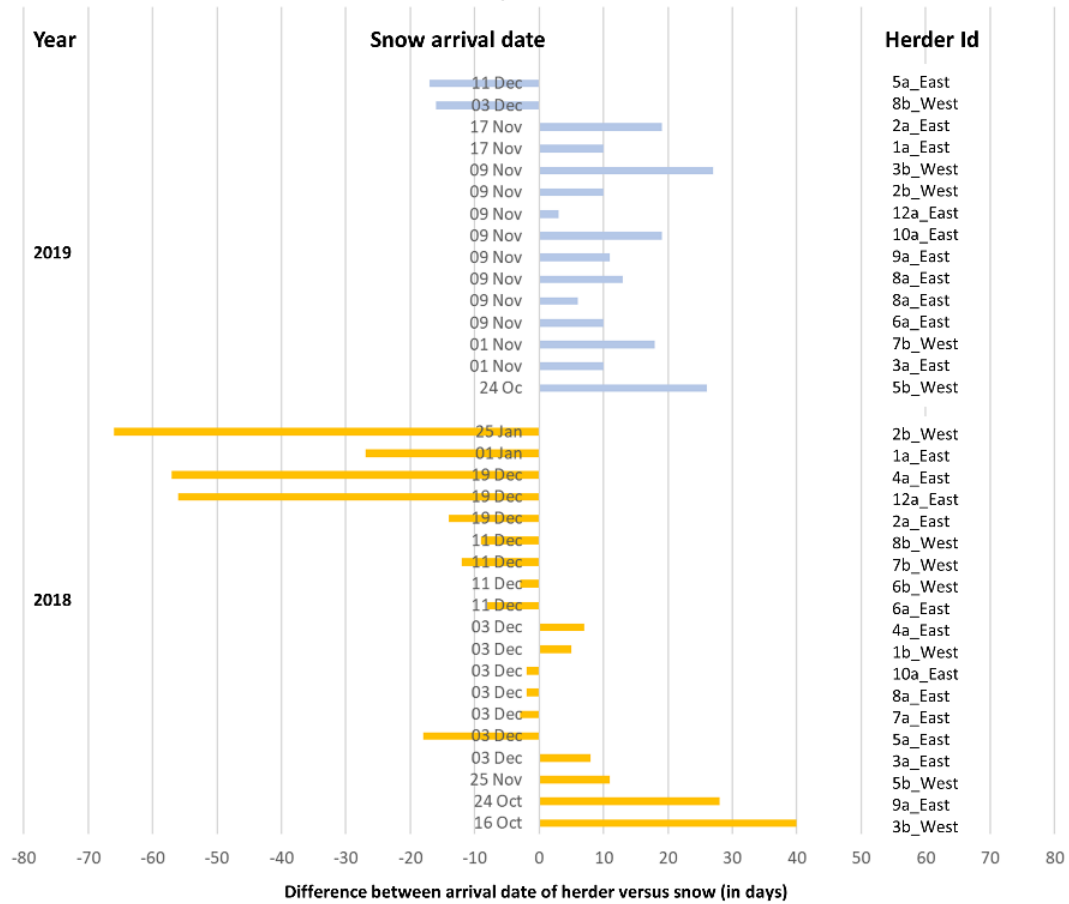


Figure B3: Herder arrival date versus date of first permanent snow cover at winter camps in the Great Gobi B Strictly Protected Area, Mongolia, in 2018 and 2019.

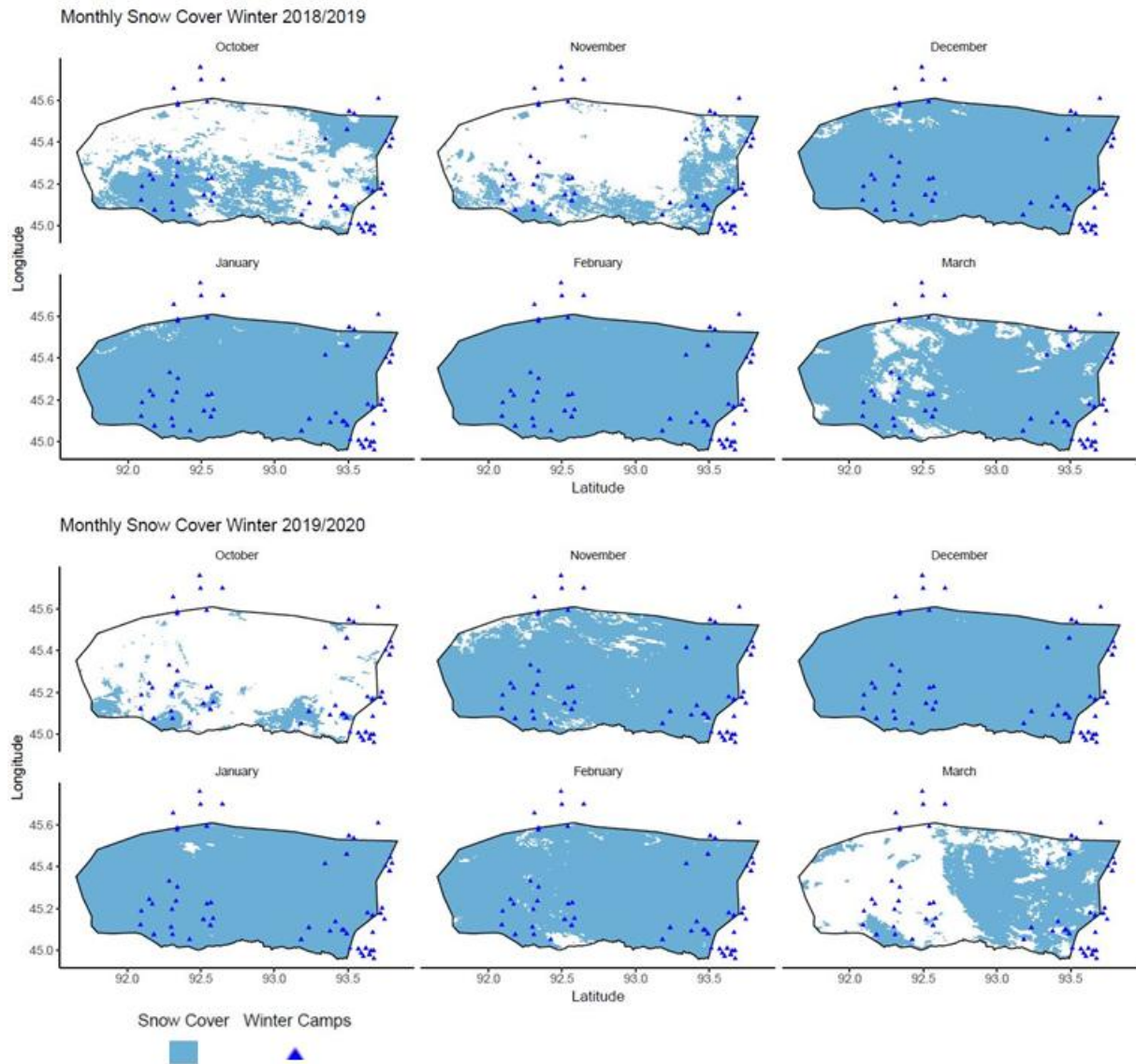


Figure B4: Monthly snow cover in winter 2018/2019 and winter 2019/2020 in the Great Gobi B Strictly Protected Area, Mongolia. Blue represents snow cover, white shows areas without snow. Blue triangles show the general location of winter camps used by the pastoralists based on GPS data.

Table B2: All candidate models that we used to estimate daily walking distances (WalkDist) by small livestock in the Great Gobi B Strictly Protected Area, Mongolia, based on GPS movement data collected in autumn 2018, spring 2019, summer 2019 and autumn 2019. The explanatory variables in the models were: enhanced vegetation index (EVI), seasonal camp location in respective years (SeasonalCamp), herd size (HerdSize) and herd ratio (HerdRatio; goats/sheep) in sheep forage units, temperature (Temp) and days since camp use start (CampStart). Herder ID was included as a random effect in all models.

Model	AIC _c	Delta AIC _c	AIC _c Weight	Log-Like- lihood
SeasonalCamp + CampStart	20007	0	1	-9996
EVI + SeasonalCamp	20028	21	0	-10007
EVI + SeasonalCamp + EVI : SeasonalCamp*	20028	21	0	-10007
SeasonalCamp + HerdSize	20029	22	0	-10008
EVI + SeasonalCamp + Temp + Seasonal- Camp : Temp + HerdRatio	20029	22	0	-10008
SeasonalCamp	20031	24	0	-10009
HerdSize + Temp	20031	24	0	-10009
SeasonalCamp + HerdRatio	20033	26	0	-10009
EVI + SeasonalCamp + EVI : SeasonalCamp + HerdRatio	20033	26	0	-10009
EVI + Temp	20736	729	0	-10363
Temp	20800	793	0	-10396
Temp + CampStart	20800	793	0	-10396
EVI + CampStart	20886	879	0	-10438
CampStart	20901	894	0	-10447
HerdSize + CampStart	20901	894	0	-10447
EVI + HerdSize	20955	948	0	-10472
HerdSize	20955	948	0	-10473
HerdRatio + Temp	20955	948	0	-10473
EVI	20960	953	0	-10476
EVI + HerdRatio	20962	955	0	-10476
HerdRatio	20962	955	0	-10477
HerdRatio + CampStart	20962	955	0	-10477

*The division sign (:) represents an interaction between two explanatory variables

Table B3: All candidate models that we used to estimate daily maximum walking distances by small livestock from camps (MaxDist) in the Great Gobi B Strictly Protected Area, Mongolia, based on GPS movement data collected in autumn 2018, spring 2019, summer 2019 and autumn 2019. The explanatory variables in the models were: enhanced vegetation index (EVI), seasonal camp location in respective years (SeasonalCamp), herd size (HerdSize) and herd ratio (HerdRatio; goats/sheep) in sheep forage units, temperature (Temp) and days since camp use start (CampStart). Herder ID was included as a random effect in all models.

Model	AIC _c	Delta AIC _c	AIC _c Weight	Log-Likelihood
SeasonalCamp + CampStart	14869	0	1	-7428
SeasonalCamp + HerdSize	14985	116	0	-7485
SeasonalCamp	14988	119	0	-7488
HerdSize + Temp	14988	119	0	-7488
EVI + SeasonalCamp	14989	120	0	-7487
EVI + SeasonalCamp + EVI : SeasonalCamp	14989	120	0	-7487
SeasonalCamp + HerdRatio	14991	121	0	-7488
EVI + SeasonalCamp + EVI : SeasonalCamp + HerdRatio	14991	121	0	-7488
EVI + CampStart	15216	347	0	-7603
EVI + SeasonalCamp + EVI : SeasonalCamp + HerdSize	15216	347	0	-7603
CampStart	15240	371	0	-7616
HerdSize + CampStart	15240	371	0	-7616
EVI + Temp	15358	489	0	-7674
Temp	15368	499	0	-7680
Temp + CampStart	15368	499	0	-7680
HerdSize	15388	519	0	-7690
HerdRatio + Temp	15388	519	0	-7690
EVI + HerdSize	15389	520	0	-7690
EVI	15395	526	0	-7694
HerdRatio	15396	527	0	-7694
HerdRatio + CampStart	15396	527	0	-7694
EVI + HerdRatio	15397	528	0	-7694

*The division sign (:) represents an interaction between two explanatory variables

Table B4: All candidate models that we used to estimate daily pasture time (PastureTime) by small livestock in the Great Gobi B Strictly Protected Area, Mongolia, based on GPS movement data collected in autumn 2018, spring 2019, summer 2019 and autumn 2019. The explanatory variables in the models were: enhanced vegetation index (EVI), seasonal camp location in respective years (SeasonalCamp), herd size (HerdSize) and herd ratio (HerdRatio; goats/sheep) in sheep forage units, temperature (Temp) and days since camp use start (CampStart). Herder ID was included as a random effect in all models.

Model	AIC _c	Delta AIC _c	AIC _c Weight	Log-Like- lihood
EVI + Temp	17058	0	1	-8524
Temp	17192	133	0	-8592
Temp + CampStart	17192	133	0	-8592
EVI + SeasonalCamp	17348	290	0	-8667
EVI + SeasonalCamp + EVI : SeasonalCamp*	17348	290	0	-8667
SeasonalCamp + CampStart	17469	410	0	-8727
SeasonalCamp	17478	420	0	-8733
HerdSize ^d + Temp	17478	420	0	-8733
SeasonalCamp + HerdRatio	17479	421	0	-8733
EVI + SeasonalCamp + EVI : SeasonalCamp + HerdRatio	17479	421	0	-8733
SeasonalCamp + HerdSize	17480	422	0	-8733
EVI + CampStart	17690	632	0	-8840
EVI + SeasonalCamp + EVI : SeasonalCamp + HerdSize	17690	632	0	-8840
EVI	17691	633	0	-8841
EVI + HerdSize	17692	633	0	-8841
EVI + HerdRatio	17693	634	0	-8841
CampStart	18209	1151	0	-9101
HerdSize + CampStart	18209	1151	0	-9101
HerdRatioHerdRatio	18240	1182	0	-9116
HerdRatioHerdRatio + CampStart	18240	1182	0	-9116
HerdSize	18241	1183	0	-9117
HerdRatioHerdRatio + Temp	18241	1183	0	-9117

*The division sign (:) represents an interaction between two explanatory variables

Table B5: Liveweight [kg] of goat and sheep breeds divided into sex occurring in the area around the Great Gobi B Strictly Protected Area, Mongolia. All selected animals were adults (>2 years old). Presented is own data and literature data from Jamsran et al. (2018).

Livestock species	Breed	Sex	Liveweight [kg]	
			Spring (April - May)	Autumn (October)
Goat	Mongolian native (own data)	Male	50.0	63.0
		Female	32.0	41.0
	Mongolian native (literature data)	Male	42.0	55.0
		Female	30.0	40.0
	Altai red (literature data)	Male	50.0	64.0
		Female	38.0	48.0
	Uuliin brow (literature data)	Male	42.0	58.0
		Female	28.0	39.0
Sheep	Mongolian native (own data)	Male	58.0	70.0
		Female	42.0	55.0
	Mongolian native (literature data)	Male	45.0	60.0
		Female	38.0	48.0
	Gobi-Altai (literature data)	Male	53.0	68.0
		Female	38.0	53.0
	Sutai strain (literature data)	Male	52.0	65.0
		Female	39.0	53.0
	Torguud (literature data)	Male	55.0	65.0
		Female	42.0	50.0

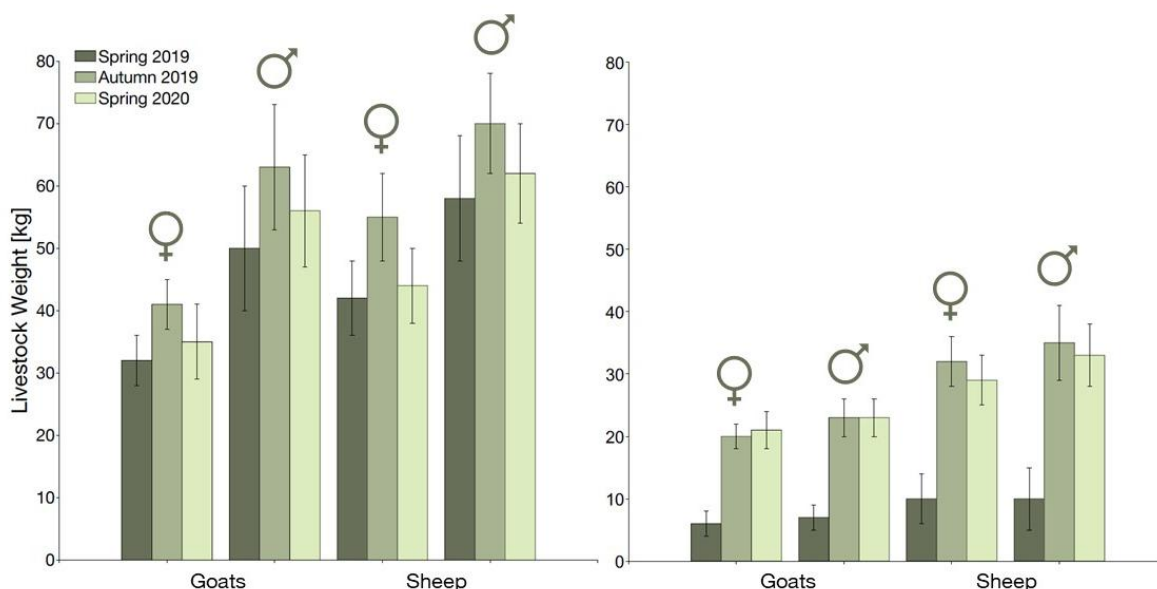


Figure B5: Weight [kg] of individually marked adult goats and sheep (left) and their young of the year (right), divided into female (♀) and male (♂) across three seasons in the Great Gobi B Strictly Protected Area, Mongolia. Whiskers show the standard deviation. Data were collected in April 2019/2020 and October 2019, N = 228.

Table B6: Number of goats and sheep in sheep forage units (1 sheep = 0.9 goat), herd ratio (goat/sheep) and herd size of 19 livestock herders in 2018 in the Great Gobi B Strictly Protected Area, Mongolia.

Herder ID	No. of Goats	No. of Sheep	Herd_Ratio	Herd_Size
1a_East	675	300	2.25	975
2a_East	360	200	1.80	560
3a_East	270	150	1.80	420
4a_East	720	450	1.60	1170
5a_East	675	550	1.23	1225
6a_East	576	340	1.69	916
7a_East*	283.5	20	14.18	303.5
8a_East	270	150	1.80	420
9a_East	355.5	285	1.25	640.5
10a_East	702	800	0.88	1502
12a_East	252	170	1.48	422
1b_West	540	1100	0.49	1640
2b_West	450	700	0.64	1150
3b_West	540	200	2.70	740
4b_West	459	600	0.77	1059
5b_West	225	300	0.75	525
6b_West	450	300	1.50	750
7b_West	274.5	155	1.77	429.5
8b_West	373.5	255	1.46	628.5

*This dataset was excluded from the analysis as the herd ratio was very extreme.

Appendix C

Table C1: Questionnaire Great Gobi B SPA

Date: Time:

I. Household information:

- 1) Interview number (ID): (Everything will be anonymous and the name will be left out)
- 2) Main interviewee partner:..... Age:
Family
name:.....
- 3) For how long have you / your family been a herder household?:
- 4) Were you born and raised in this region (ask for aimag, soum and bag?:
- 5) Location of current camp (GPS):
- 6) Which camp is this: ☐ Fall/Autumn ☐ Winter ☐ Spring ☐ Summer
- 7) Number of people associated with this household: *use household network sheet*
- 8) What is the normal migration route: *use camp sheet*

II. Livestock situation:

- 1) How many animals do you graze?

		Goats	Sheep	Cattle	Yaks	Horses	Camels
How many animals do you graze?							
How (km) far from your ger do animals graze?	Sum-mer						
	Winter						

- 2) How many dogs do you have:
- 3) Has the total number of the livestock you graze within the last 3 years:

☐ Increased ☐ Decreased ☐ Remained the same

4) Would you like to increase the livestock numbers in future? ☐ Yes ☐ No

If yes: Why and what species?

.....

5) Ownership of herd?

☐ Own %: ☐ Other family members %: ☐ Animals of someone else (unrelated)%:

6) Herding regime?

	At ger at night		Herder with flock		Only check-ups			Other
	inside corral	next to ger	whole day	part day	≥1 / day	≥1 / week	≥1 1 / month	
Sheep & goats								
Cattle								
Yaks								
Horses								
Camels								

6) Who is herding your animals?

.....

7a) How far (km) from the ger does the herder walk/ride every-day?.....

7b) Do you herd with:

☐ by foot ☐ on horse ☐ with motorbike ☐ with camel

8) When does the herder leave the ger in the morning hour and when do you come back in the afternoon?

	Time leaving	Time coming back
Summer		
Winter		

9) Who in your household is mainly responsible for the animals in daily / annual routines?

Task	Responsible person(s) in household	Season of main work load
Herding		
Milking		
Shearing wool		
Combing cashmere		
Marking / castrating		
Slaughtering		
Selling/purchasing		
Caring for young animals		
Caring for sick animals		

IV. Livestock household economy:

1) To which percentage does herding contribute to your total income?

☐ 0 – 25 % ☐ 25 – 50 % ☐ 50 – 75 % ☐ 75 – 100 %

2) Do you have any other sources of income? ☐ Yes ☐ No

If, yes:

	% of overall household income
Park related income (what?)	
Agricultural activity (what?)	
Trade, small shop, souvenirs (what?)	
Support from family member who is working in village/town	
Other, e.g. governmental grants (pension, child grant, disability grant)	

3) What are your household expenses for different items over the year?

Item	Expenses in %	Has the importance of these expenses changed and if so in which direction?
Food		
Clothing		
Health care		
Health insurance		
Retirement		
Education of children		
Travelling / transportation		
Recreation		
Livestock health		
Equipment		
Other: _____		

4) Which products do you sell?

Animal	Products: Milk or milk products, Wool, Cashmere, Meat, Hide, Animals	Revenue gain (high, moderate, low)
Goat		
Sheep		
Cattle		
Yak		
Horse		
Camel		

5) What prices do you fetch for:

Product	In MNT	Earnings in relative importance (high, low, medium, not important)
Milk [L]		
Wool [kg] / Cashmere [kg]		
Meat [kg]		
Animals [price per animals]		
Hide [price per hides]		

7) How many animals do you need for a good living?

.....

Minimum, what is a good herd

size.....

Can the herds be too big?

.....

.....

Table C2: Interview Statistics of 125 herder household interviews in 2017/2018 in the Great Gobi B strictly protected area in Mongolia. When a couple was interviewed the age of the male partner was recorded.

ID	Main interview partner(s)	Age of main interview partner	Belongs to district
1	female	30	Altai soum
2	male	40	Bugat soum
3	male & female	54	Bugat soum
4	male	58	Bugat soum
5	male	53	Bugat soum
6	male & female	63	Bugat soum
7	male	46	.
8	male & female	50	Bugat soum
9	male	43	.
10	female	58	Bugat soum
11	male	46	.
12	male	57	Bugat soum
13	female	31	Bugat soum
14	male	34	Bugat soum
15	female	28	Tonkhil soum
16	male & female	61	Tonkhil soum
17	female	30	Tonkhil soum
18	male	43	Altai soum
19	male	40	Altai soum
20	male	33	Altai soum
21	male & female	33	Altai soum
22	female	29	Bugat soum
23	male & female	47	Bugat soum
24	female	33	Bugat soum
25	male & female	49	Bugat soum
26	male	41	Altai soum
27	male	54	Altai soum
28	female	51	Altai soum
29	male	55	Altai soum
30	male	34	Altai soum
31	son	26	Altai soum
32	male	31	Altai soum
33	male	22	Altai soum
34	male & female	32	Bugat soum
35	male & female	61	Bugat soum
36	male	57	
37	male & female	39	Bugat soum
38	male & female	60	Bugat soum
39	male & female	66	Bugat soum
40	male	24	Bugat soum
41	male & female	43	Tonkhil soum
42	male	36	Tonkhil soum
43	female	50	Altai soum
44	male	33	Altai soum
45	male	56	Altai soum
46	male & female	43	Bugat soum

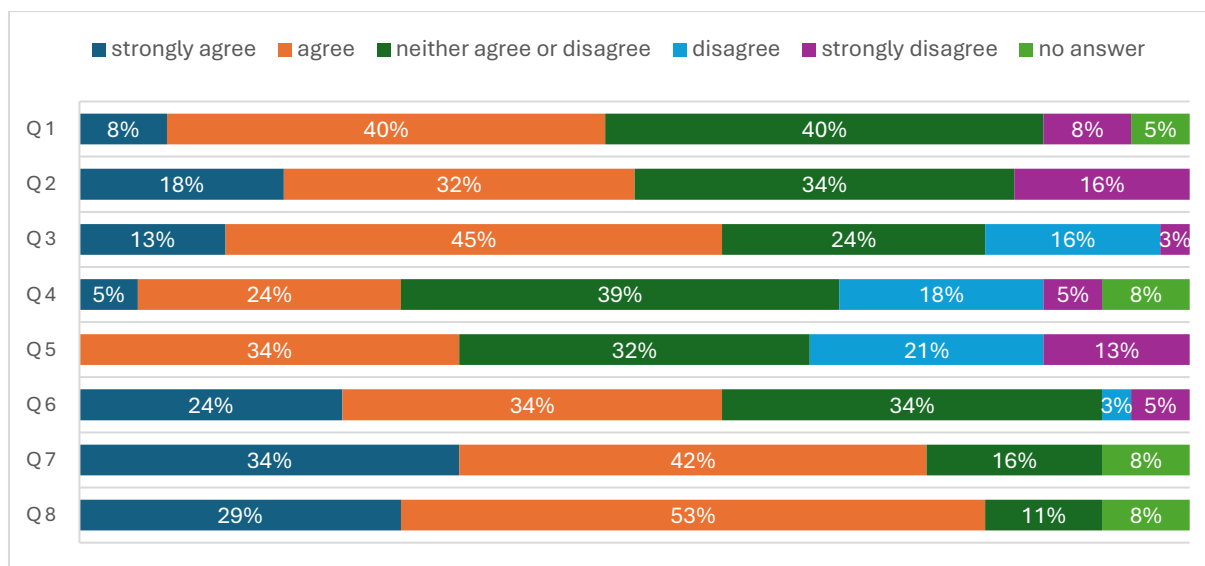
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47	male	38	Tonkhil soum
48	female	43	Bugat soum
49	male	17	Bugat soum
50	female	41	Tonkhil soum
51	male	38	Bugat soum
52	female	59	Tonkhil soum
53	male	67	Bugat soum
54	female	48	Bugat soum
55	female	60	Bugat soum
56	female	53	Bugat soum
57	male	27	Mankhan soum
58	male & female	40	.
59	male & female	42	Bugat soum
60	male & female	50	Bugat soum
61	female	61	Bugat soum
62	female	41	Bugat soum
63	female	55	Bugat soum
64	male	51	Bugat soum
65	female	64	Bugat soum
66	male	56	Bugat soum
67	male	41	Bugat soum
68	male	70	Altai soum
69	male	38	Altai soum
70	male	34	Bulgan soum
71	female	53	Altai soum
72	male	39	Altai soum
73	male & female	51	Altai soum
74	male	57	Altai soum
75	female	.	Altai soum
76	male	60	Mankhan soum
77	male	22	Altai soum
78	male	22	Altai soum
79	male & female	51	Altai soum
80	female	45	Altai soum
81	female	42	Altai soum
82	female	20	Altai soum
83	male	54	Bulgan soum
84	male	42	Altai soum
85	male	39	Altai soum
86	male	48	Altai soum
87	male	39	Altai soum
88	male	36	Tsetseg soum
89	male & female	31	Altai soum
90	male	45	Altai soum
91	male	33	Altai soum
92	male	34	Altai soum
93	female	27	Altai soum
94	female	59	Altai soum
95	female	28	Altai soum
96	male	66	Altai soum
97	male	57	Altai soum

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98	male & female	57	Altai soum
99	female	58	Altai soum
100	female	48	Altai soum
101	male	67	Altai soum
102	female	49	Altai soum
103	female	25	Altai soum
104	male	37	Altai soum
105	male	30	Altai soum
106	female	43	Altai soum
107	male	49	Altai soum
108	female	43	Altai soum
109	male	38	Altai soum
110	male	29	Altai soum
111	male	59	Altai soum
112	male	49	Altai soum
113	male	20	Altai soum
114	male	32	Altai soum
115	male & female	48	Altai soum
116	male & female	67	Altai soum
117	male	31	Altai soum
118	male	49	Altai soum
119	male	45	Altai soum
120	male	64	Altai soum
121	male & female	32	Uyench soum
122	male	39	Altai soum
123	male	41	Altai soum
124	male	66	Altai soum
125	female	60	Altai soum

Figure C1: State of collaboration between the protected area administration and local herders in the Great Gobi B strictly protected area in Mongolia 2019. Results of the survey on the participation of herders in the management of protected areas (N=36)



Q1: Living close to the Great Gobi B SPA is good for the livelihood of my family and me.

Q2: My family and I always follow all the regulations and recommendations given by the Great Gobi B SPA administration.

Q3: My family and I participate in consultative meetings with the Great Gobi B SPA to express our ideas about regulations and recommendations developed by the Great Gobi B SPA administration.

Q4: It is certain that my views are considered in decision-making by the National Park Administration.

Q5: The Great Gobi B SPA administration develops the management plan based on mutual understanding between stakeholders.

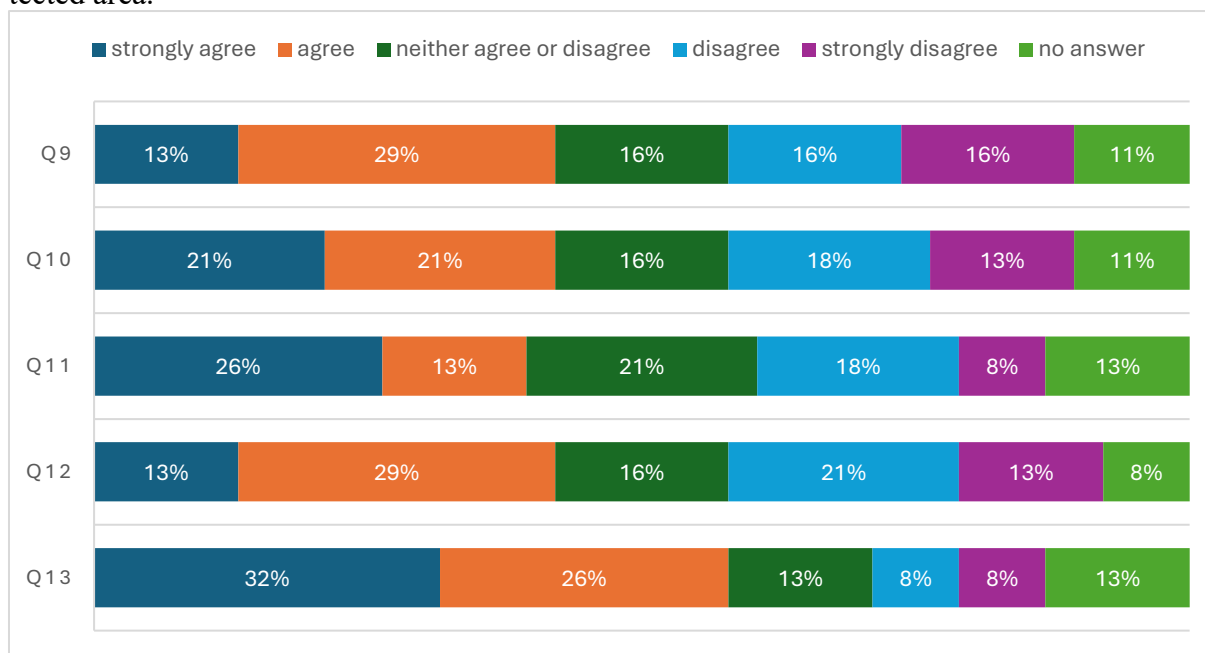
Q6: The Great Gobi B SPA administration regularly and openly presents their action plan for co-operation.

Q7: Locals and Great Gobi B SPA administration should collaborate on the conservation of nature and usage of natural resources.

Q8: The Great Gobi B SPA administration needs to improve its co-operation with herders and local communities in order to ensure environmental protection and sustainable use of natural resources.

Figure C2: Conflicts between stakeholders in the Great Gobi B strictly protected area in Mongolia 2019. Results of the survey on the participation of herders in the management of protected areas (N=36)

“I have faced the following challenges or troubles while living in the buffer zone of the protected area.”



Q9: Pasture land is limited for small livestock (sheep and goats).

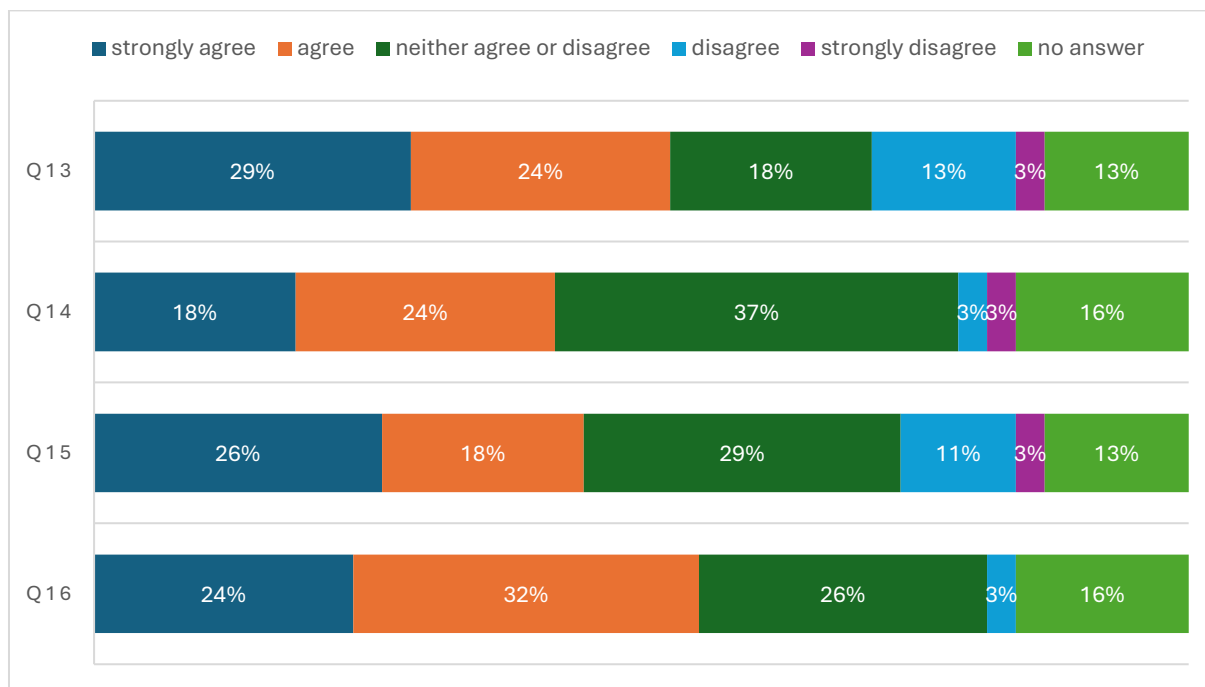
Q10: Ability to move and rotate pastures with livestock is limited.

Q11: Pasture for horses is limited during the summer season due to Takhi breeding.

Q12: There are misunderstandings with the Great Gobi B SPA administration when transiting through the protected area.

Figure C3: Challenges of herders in regard to communication with the Great Gobi B strictly protected area in Mongolia 2019. Results of the survey on the participation of herders in the management of protected areas (N=36)

“I have the following challenges in regard to co-operating, and participating in environmental conservation and sustainable use of natural resources in the Great Gobi B SPA.”



Q13: Information about meetings and workshops is not distributed sufficiently to reach everyone, especially those in remote areas.

Q14: The Great Gobi B SPA administration does not organize meetings for listening to the views of local people.

Q15: The Great Gobi B SPA administration does not take action to resolve complaints and views of the local people.

Q16: There is lack of information and understanding of the rights of the community regarding co-operation and participation in the use of natural resources for environmental protection.

Table C3: Future perspectives of 9 focus group participants (“young herders”) on their herder lifestyle in the Great Gobi B strictly protected area, Mongolia 2019.

Why did you become a herder? Are your siblings herders too? Did your parents envision you to become a herder?	Is there anything that will force you to change your lifestyle? Like to move to the town/city. Did you consider moving to the town/city?	What kind of school/university degree do you have?	If you would have an alternative job opportunity, would you still want to continue the herder lifestyle?
Does not know	Will continue to herd livestock	Primary school	Yes. I will herd livestock.
Parents are herders	Will continue to herd livestock	Secondary education	No
Relatives are herders	Will continue to herd livestock	Secondary education	Yes. I will herd livestock.
My husband is herder	Will continue to herd livestock	Secondary education	Maybe I will choose a permanent job.
Parents are herders	Will continue to herd livestock	Secondary education	Yes. I will herd livestock.
Parents are herders	I would like to move to the town	Secondary education	Yes. I will herd livestock.
Parents are herders	I would like to move to the town	Secondary education	Yes. I will herd livestock.
Parents are herders	I will continue to herd livestock	Secondary education	Maybe I will choose a permanent job.
Husband is herder	I would like to move to the town	Secondary education	No
No answer	No answer	Secondary education	No answer

Table C4: Advantages and challenges of living a herder lifestyle in Mongolia reported by N=9 participants in a focus group discussion at the Great Gobi B Strictly Protected Area in Mongolia 2019.

Perspective	Advantages of living as a herder in Mongolia	Challenges of living as herder in Mongolia
Livestock Husbandry	- No time limitation - Own production of cashmere, wool and dairy products - Working for oneself - Huge territory available for herding	- Climate: snow storms and hard winters - Limited growth of grass and dry summer - Limited communication options (phone networks & internet) - Fluctuating market prices of cashmere, wool, and meat
Pasture Use	- Untouched rangelands - Livestock gains enough fat for meat and dairy production - Practice camp rotation during four seasons to protect the rangeland - Consider rangeland use and its resources	- Staying for a long time at the same place destroys the rangeland - Use rangeland for seasonal grazing - A lot of snow during winter bring troubles - Herders winter camps are close to each other, sometimes this brings minor conflicts
Social and Household	(No advantages mentioned by the focus group)	- Lack of public/governmental services: Live far from school and kindergarten; Transfer of children to different schools influence their study quality - Mostly girls go to schools and university; Boys are mostly responsible for herding livestock - Safety is not provided, no police, no emergency service - Difficult to get medical/health services - Limited communication options (phone networks & internet)

Table C5: Answers of focus group discussions with “young herders” of the Great Gobi B Strictly Protected Area, Mongolia, in November 2019. Questions were answered under the perspectives of livestock husbandry, pasture use and social and household aspects.

Questions	Livestock Husbandry	Pasture Use	Social and Household
Traditional skills	- Marking animals through cutting ears - Separating animals (carrying females and males) - Livestock breeding	- Herding livestock (small livestock always with a herder) - Get up early in the morning - Separate animals (carrying females and males) - Protecting the winter camp from wind and cold - Prepare fodder for winter - Preparing dairy products	- Preparing dairy products - Preparing fodder / hay for winter - Use the winter camps of grandparents - Herding livestock
Traditional skills for coping in winter	- Separate weak and young animals - Caring for weak and young animals at the warm winter camp - Feed additional hay/fodder - Herd livestock in a sheltered area with enough grass - Have a good supply of pasture for the winter (be well prepared)	- Well protected winter camp (wind and snow) - Consider pasture and winter rangeland - Prepare “khujir” a white salty mineral for livestock and enough water	- Feed livestock additional fodder/hay - Clean winter area from snow and ice - Care for weak and young livestock
Incentive to change traditional herding / Already practiced changes	- No. Traditional herding is based on huge experience and it has worked for hundreds of years	- Give ownership status for rangeland	- Adapt to use motorbikes for herding. Before we only used horses, camels or walked for herding - Get weather information from TV and radio and decide then where to herd livestock
Influence of media/internet on herding	- Get weather forecast from TV and radio - Learning about experiences from others	- Get weather information - Get information on new laws regarding animal husbandry	- Get information on lost animals - Exchange experiences with each other - Get recent information; helps to not stay behind in development
Influence of conservation activities on herder lifestyle	- Wildlife number increase influences rangeland degradation and it can affect our animal husbandry	- Conservation activities do influence rangeland use - Sometimes wildlife home range is overlapping with livestock rangeland	- Will influence livestock rangeland - Wildlife home range will influence rangeland of livestock
Influence of the protected area on herder lifestyle	- There is not much influence on the lifestyle yet	- Does not influence the lifestyle - There will be an influence in the rangeland - Beneficial due to no mining exploration	- Protecting water resources of “Gashuun” - Internet connection

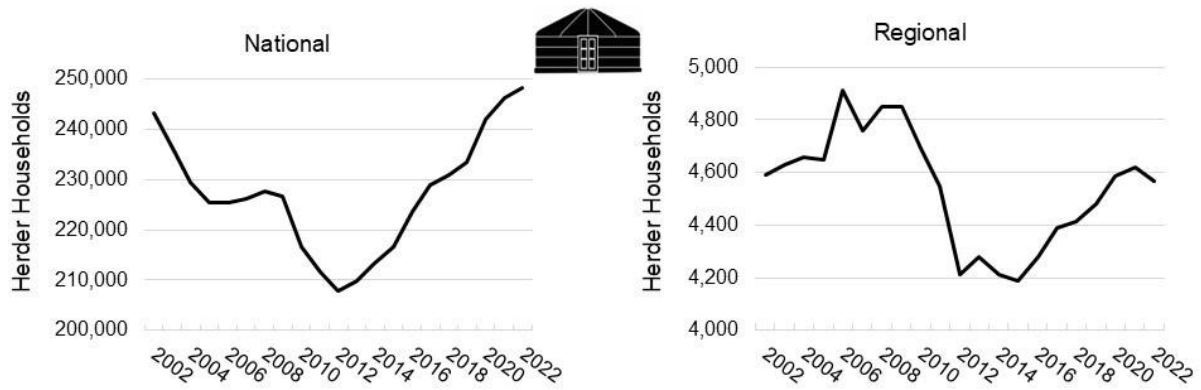


Figure C4: Herder household data in Mongolia (national) and within the five districts surrounding the Great Gobi B strictly protected area (regional) over 20 years (2002-2022; Mongolian Statistical Information, 2023).

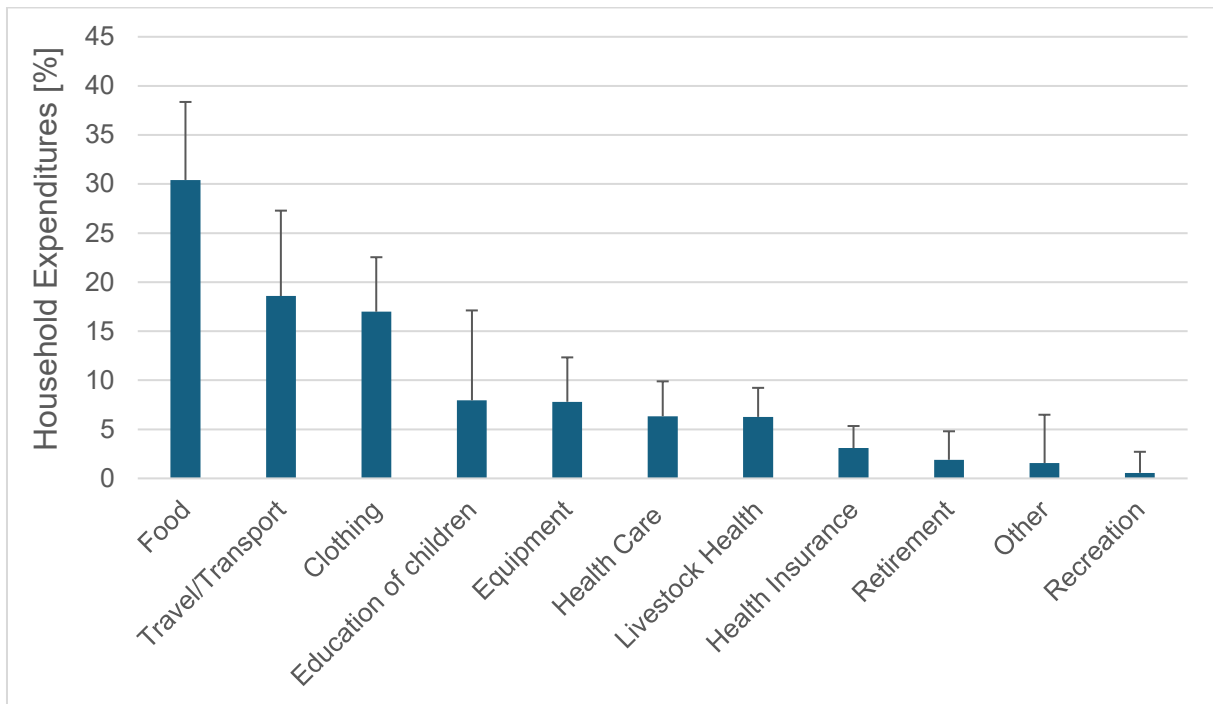


Figure C5: Detailed household expenditures [%] of N=125 herder households in the Great Gobi B Strictly Protected Area in Mongolia 2017/2018.

Table C6: Daily and seasonal tasks of herder households over the course of one year inside the Great Gobi B Strictly Protected Area, Mongolia (N =70).

Annual/Seasonal Task	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Herding												
Slaughtering for daily consumption												
Caring for offspring												
Caring for sick animals												
Marking/Castrating												
Combing cashmere												
Shearing sheep wool												
Shearing camel wool												
Milking												
Slaughtering for winter preparation												

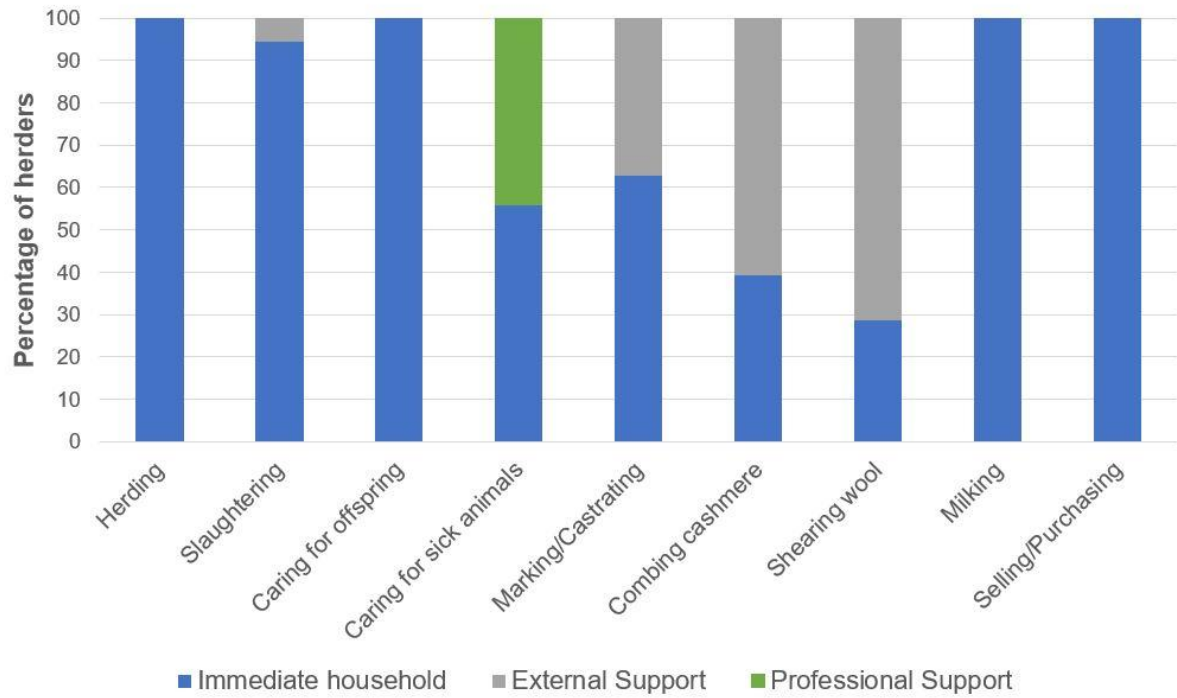


Figure C6: Responsible persons [%] for daily/seasonal routines of herder households inside the Great Gobi B Strictly Protected Area, Mongolia (N = 70).